TEENAGERS' ABILITY TO MASTER DEDUCTIVE ARGUMENTS BASED ON FOUR BASIC PRINCIPLES OF CONDITIONAL AND DISJUNCTIVE REASONING

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CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

ABSTRACT

A 48 item reasoning test was administered to 210 teenage subjects. On the basis of their educational status, the subjects were classified into three groups: fourth formers, sixth formers and university students. There were 70 subjects in each group with equal numbers of males and females. The mean ages of these three groups were 14.95, 17.16 and 18.96 years respectively.

The reasoning test assessed the subjects' ability to master deductive arguments on four basic principles of conditional and disjunctive reasoning with both concrete and abstract content. The data were analysed using parametric analysis of variance and certain non-parametric statistics. The latter form of analysis was carried out as a check on the parametric analysis of variance results. This was done because the normality assumptions of the parametric analysis of variance were not completely fulfilled. The results of the non-parametric analyses were highly similar to those of the parametric analysis of variance.

The results indicate that mastery of the four principles of deductive logic improves with age. Further, the results indicate no difference between the two sexes relative to their performance on the reasoning test. The results also indicate that subjects find no difference in difficulty between items within the concrete and the abstract content. The results also show that there are differences between subjects' mastery of the detachment principle and the three principles of contraposition, conversion and inversion in conditional reasoning. In contrast, there is no difference between subjects' mastery of the four principles in disjunctive reasoning. The results also show that subjects find items within disjunctive reasoning easier to master than items within conditional reasoning. Generally, the results obtained are comparable to the findings of previous studies of teenagers' ability to master deductive arguments. Finally, several factors which influence the subjects' reasoning ability are outlined.

CHAPTER ONE

INTRODUCTION

Broadly defined, propositional logic is the logic of all systems that satisfy three conditions:

(i) There are two or more factors (variables);

(ii) Each factor can take on two discrete values; and

(iii) All combinations of these factors take on the same two values.

It is crucial that the values be mutually exclusive and not overlap in any way. In principle, propositional logic deals with systems in which there are any number of variables and any number of mutually exclusive values. But the simplest possible example of propositional logic, the example which we shall consider, consists of two variables and two values. By convention, the variables are called propositional functions and are denoted by "p" and "q". The two values may be just about anything, but they are usually called true and false to emphasize their mutual exclusiveness.

Suppose we let our first propositional function, p, be "x invented the telephone" and we let our second propositional function, q, be "x was President of the United States". When a specific person is substituted for the x in either statement, the statement becomes either true or false. For example, p is true if Graham Bell is substituted but is false if Aristotle is substituted. Similarly q is true if Lincoln is substituted but is false if Caesar is substituted. The substitution of a specific person

for the x in either statement is called interpretation. When a propositional function is interpreted and becomes true or false, it is called a proposition. This is where the "propositional" in propositional logic comes from.

Through the process of interpretation, p and q each becomes true or false. Consequently, there are four possible results of interpreting both statements:

(i) p = true and q = true (e.g. Graham Bell invented the telephone and Lincoln was President of the United States);

(ii) p = false and q = true (e.g. Aristotle invented the telephone and Lincoln was the President of the United States);

(iii) p = true and q = false (e.g. Graham Bell invented the telephone and Caesar was President of the United States); and

(iv) p = false and q = false (e.g. Aristotle invented the telephone and Caesar was President of the United States).

Since there are exactly four possible outcomes of interpreting p and q, we may think of p and q as forming a new compound propositional function which we denote by p + q. The compound proposition p + q takes on exactly four interpretations which correspond to four possible outcomes of interpreting p and q. Since all propositional functions in our system must be either true or false once they are interpreted, p + q must be either true or false when it is assigned one of its four interpretations. Suppose we assign p + q one of its four interpretations one after the other. It

follows, there are 4^2 or 16 possible true-false outcomes. At one extreme, it might be that p + q turns out to be true for all the four interpretations. At the other extreme, it might be that p + q turns out to be false for all the four interpretations. In between, there are fourteen other outcomes where p + q is true for some interpretations and false for others. These sixteen possible outcomes, along with the names that are usually given to them in propositional logic, are shown in Table 1.

Propositional logic is generally taken to be one kind of deductive logic, as in the following example:

Premises

(i) If the car is black, then it is a police car.

(ii) The car is black.

Conclusion

(iii) It is a police car.

This argument is "valid" because the conclusion follows necessarily from the premises. An invalid argument is one in which the conclusion does not necessarily follow from the premises, as in the example below.

Premises

(i) If the car is black, then it is a police car.

(ii) It is a police car.

Erroneous Conclusion

(iii) The car is black.

Obviously there could be a police car which is not black.

The relations between propositions are described by a set of symbols, the main symbols being shown in Table 2.

Table 1: The sixteen outcomes from combining two binary operations

OUTCOME	COMPONENT PROPOSITIONS				CONSTRUCTED COMBINATION
	p = true q = true	p = true q = false	p = false q = true	p = false q = false	
1. Affirmation (p*q)	t	t	t	t	$p \cdot q \vee p \cdot \bar{q} \vee \bar{p} \cdot q \vee \bar{p} \cdot \bar{q}$
2. Disjunction (p v q)	t	t	t	f	$p \cdot q \vee p \cdot \bar{q} \vee \bar{p} \cdot q$
3. Reverse Conditional[1] (p←q)	t	t	f	t	$p \cdot q \vee p \cdot \bar{q} \vee \bar{p} \cdot \bar{q}$
4. Conditional (p→q)	t	f	t	t	$p \cdot q \vee \bar{p} \cdot q \vee \bar{p} \cdot \bar{q}$
5. Nonconjunction (p/q)	f	t	t	t	$p \cdot \bar{q} \vee \bar{p} \cdot q \vee \bar{p} \cdot \bar{q}$
6. Affirmation of p(p)	t	t	f	f	$p \cdot q \vee p \cdot \bar{q}$
7. Affirmation of q(q)	t	f	t	f	$p \cdot q \vee \bar{p} \cdot q$
8. Equivalence (p ≡ q)	t	f	f	t	$p \cdot q \vee \bar{p} \cdot \bar{q}$
9. Denial of q -(q)	f	t	f	t	$p \cdot \bar{q} \vee \bar{p} \cdot \bar{q}$
10. Denial of p -(p)	f	f	t	t	$\bar{p} \cdot q \vee \bar{p} \cdot \bar{q}$
11. Nonequivalence -(p q)	f	t	t	f	$p \cdot \bar{q} \vee \bar{p} \cdot q$
12. Conjunction (p•q)	t	f	f	f	$\bar{p} \cdot \bar{q}$
13. Nonconditional -(p→q)	f	t	f	f	$p \cdot \bar{q}$
14. Nonreverse Conditional -(p←q)	f	f	t	f	$\bar{p} \cdot q$
15. Nondisjunction -(p v q)	f	f	f	t	$\bar{p} \cdot \bar{q}$
16. Negation -(p*q)	f	f	f	f	0

1 Since conditional statements assert a contingent relationship between two things, they are also referred to as statements of implication.

TABLE 2: Symbols used to show the relations between propositions.

SYMBOL	MEANING
-	not (negation)
•	and (conjunction)
v	or (disjunction)
→	if...then (conditional)

The (-) symbol refers to the fact that each and every proposition can be negated. If, for example, we have the proposition "The car is black" (symbolised by p), the negation of the proposition is "The car is not black" (symbolised by $\bar{p}$ - not p).

The symbols (•) and (v) are forms of simple addition and multiplication respectively. Consider the case in which we have another proposition "The car is a police car" (q). The addition or conjunction, of the two propositions becomes p•q and means "The car is black and the car is a police car." The multiplication of the two propositions produces p v q which means "Either the car is black or the car is a police car (or both)".

The final symbol describes the conditional relationship p→q, which means that if p is true, then q is true, or in terms of the above propositions "If the car is black, then it is a police car".

Propositional logic is ordinarily concerned with the validity of arguments utilising propositions standing alone or under the influence of one or more of these logical operators.

As propositional logic is central in human reasoning, there are reasons for wanting to know when children are capable of using and understanding them. Most of these reasons are educational. Mathematics and science comprise a major portion of the present day school curriculum. If we wish to teach mathematics and science in such a way that pupils understand the relevant concepts rather than merely learning them by rote, it is necessary to acquaint them with the forms of logical reasoning on which these concepts are based. If we then decide to teach such logical operations, we need to know when children are capable of understanding them.

There is a long history of research on the development of propositional resasoning dating back to the origins of the intelligence testing movement at the turn of the century. However, our interest is in a series of investigations dating from the early 1960's, inspired by Piaget's (1958) claim that "...the child at the concrete level (Stage II: from 7-8 to 11-12 years) cannot yet handle" propositional logic (Inhelder and Piaget, 1958; p.1). The starting point for this series of studies was a doctoral dissertation by Hill (1961).

Hill (1961) found that children (ages 6-8) were able to recognise valid conclusions derived from hypothetical premises of the following forms:

Example 1: Sentential Logic

If this is Room 9, then it is fourth grade.

This is Room 9.

Is it fourth grade?

a. Yes b. No

Example 2: Classical Syllogism

All of Ted's pets have four legs.

No birds have four legs.

Does Ted have a bird for a pet?

a. Yes b. No

Example 3: Logic of quantification

None of the pictures was painted by anyone I know.

I know Hank's sister.

Did she paint one of the pictures?

a. Yes b. No

All items consisted of two premises, a question and two possible responses, "Yes" and "No". In addition, Hill reported steady increases with age for these three types of logic, with sentential logic being easier than quantificational logic at age 6, a difference which disappeared by age 8.

Suppes (1965), commenting on these results, argued that they provided evidence "...contrary to that given by Piaget and Inhelder in that children of age 6,7 and 8 are able to deal very effectively with verbal premises that call for hypothetical reasoning and are by no means limited to 'concrete' operations".

O'Brien and Shapiro (1968) extended Hill's research by evaluating children's (ages 6-8) ability to recognise principles for which no valid conclusion was possible. In their study, two measuring instruments were used. Test A was the same test as in the Hill study; and Test B was the same as Test A except that (i) 33 of the original 100 items were "opened up" so that no necessary conclusion followed from the premises, and (ii) for every item in

Test B, a "Not enough clues" option was added to the "Yes" and "No" response choices provided in Test A. "Opened up" Test B items might be:

Example 1: Sentential Logic

If this is Room 9, then it is fourth grade.

This is not Room 9.

Is it fourth grade?

a. Yes b. No c. Not enough clues

Example 2: Classical syllogism.

Some of Ted's pets have four legs.

No birds have four legs.

Does Ted have a bird for a pet?

a. Yes b. No c. Not enough clues

Example 3: Logic of quantification

Some of the pictures were painted by people I know.

I know Hank's sister.

Did she paint one of the pictures?

a. Yes b. No c. Not enough clues

As in the Hill study, the children had considerable success in recognising valid conclusions in the three types of logic. But they experienced great difficulty in recognising invalid conclusions in each type of logic and showed slow growth in this ability.

Donaldson (1963) conducted longitudinal studies with students 10-12 and 12-14 years of age. She presented these students with three verbal problems in class logic involving syllogisms and found that their ability to infer

valid conclusions increased with age. They showed no improvement, however, in the ability to recognise invalid patterns of inference.

Ennis and Paulus (1965) discovered large differences in raw scores, difficulty indices, and percentages of mastery for specific principles of class and conditional reasoning at given grade levels (4-12). They reported that the greatest improvement in the mastery of specific principles, as children grew older, was that for the invalid principles.

While the findings of these investigations are valuable, they are restricted in scope for one or more of the following reasons:

(i) Only one type of reasoning was tested;

(ii) Only valid principles were tested;

(iii) The principles tested in the different types of reasoning were dissimilar in terms of logical structure; and

(iv) The tests for each type of reasoning were not administered to the same students.

In trying to overcome these limitations, a number of researchers (e.g. Brainerd, 1976-1977; Ennis, 1976, 1978; Roberge, 1970) have been particularly concerned with standardising the elementary principles of deductive logic before administering them. Amongst these researchers, the work of Ennis has been the most extensive. In Table 3, the standard elementary principles of deductive logic are presented (adapted from Ennis, 1976). Part A of the table, "Formally Valid Moves" guarantees a valid argument (i.e., an argument in which the conclusion follows necessarily from the premises). In the "Formally

TABLE 3

RELATIONAL LOGICAL PRINCIPLES: PRINCIPLES OF CONDITIONAL, CLASS, AND ALTERNATION LOGIC

	CONDITIONAL LOGIC			ALTERNATION LOGIC	
	Propositional Logic	Propositional-Function Logic	CLASS LOGIC	Propositional Logic	Propositional-Function Logic
	A. Formally Valid Moves				
1. Detachment	If p, then q.[a] p. ———[b] q.	(For all x) if x is an A, then x is a B.[a] n is an A.[a] ——— n is a B.	All A's are B's. n is an A. ——— n is a B.	Either p or q.[c] Not p. ——— q.	(For all x) either x is an A or x is a B.[c] n is not an A. ——— n is a B.
2. Particular transitivity	If p, then q. If q, then r. p. ——— r.	(For all x) if x is an A, then x is a B. (For all x) if x is a B, then x is a C. n is an A. ——— n is a C.	All A's are B's. All B's are C's. n is an A. ——— n is a C.	Either p or q. Either not q or r. Not p. ——— r.	(For all x) either x is an A or x is a B. (For all x) either x is not a B or x is a C. n is not an A. ——— n is a C.
3. Full transitivity	If p, then q. If q, then r. ——— If p, then r.	(For all x) if x is an A, then x is a B. (For all x) if x is a B, then x is a C. ——— (For all x) if x is an A, then x is a C.	All A's are B's. All B's are C's. ——— All A's are C's.	Either p or q. Either not q or r. ——— Either p or r.	(For all x) either x is an A or x is a B. (For all x) either x is not a B or x is a C. ——— (For all x) either x is an A or x is a C.
4. Particular contraposition	If p, then q. Not q. ——— Not p.	(For all x) if x is an A, then x is a B. n is not a B. ——— n is not an A.	All A's are B's. n is not a B. ——— n is not an A.	Either p or q. Not q. ——— p.	(For all x) either x is an A or x is a B. n is not a B. ——— n is an A.

TABLE 3 (*Continued*)

	Conditional Logic		Class Logic	Alternation Logic	
	Propositional Logic	Propositional-Function Logic		Propositional Logic	Propositional-Function Logic
	A. Formally Valid Moves				
5. Full contraposition	If p, then q. ——— If not q, then not p.	(For all x) if x is an A, then x is a B. ——— (For all x) if x is not a B, then x is not an A.	All A's are B's. ——— All non-B's are non-A's.	Either p or q. ——— Either q or p.	(For all x) either x is an A or x is a B. ——— (For all x) either x is a B or x is an A.
6. Biconditionality:[d]					
a) Forward positive detachment	p if and only if q. p. ——— q.	(For all x) x is an A if and only if x is a B. n is an A. ——— n is a B.	All and only A's are B's. n is an A. ——— n is a B.	p or q, but not both. Not p. ——— q.	(For all x) x is an A or x is a B, but not both. n is not an A. ——— n is a B.
b) Reverse positive detachment	p if and only if q. q. ——— p.	(For all x) x is an A if and only if x is a B. n is a B. ——— n is an A.	All and only A's are B's. n is a B. ——— n is an A.	p or q, but not both. Not q. ——— p.	(For all x) x is an A or x is a B, but not both. n is not a B. ——— n is an A.
c) Forward negative detachment	p if and only if q. Not p. ——— Not q.	(For all x) x is an A if and only if x is a B. n is not an A. ——— n is not a B.	All and only A's are B's. n is not an A. ——— n is not a B.	p or q, but not both. p. ——— Not q.	(For all x) x is an A or x is a B but not both. n is an A. ——— n is not a B
d) Reverse negative detachment	p if and only if q. Not q. ——— Not p.	(For all x) x is an A if and only if x is a B. n is not a B. ——— n is not an A.	All and only A's are B's. n is not a B. ——— n is not an A.	p or q, but not both. q. ——— Not p.	(For all x) x is an A or x is a B, but not both. n is a B ——— n is not an A

	B. Formally Invalid Moves				
7. Particular conversion	If p, then q. q. ——— p.	(For all x) if x is an A, then x is a B. n is a B. ——— n is an A.	All A's are B's. n is a B. ——— n is an A.	Either p or q. q. ——— Not p.	(For all x) either x is an A or x is a B. n is a B. ——— n is not an A.
8. Full conversion	If p, then q. ——— If q, then p.	(For all x) if x is an A, then x is a B. ——— (For all x) if x is a B, then x is an A.	All A's are B's. ——— All B's are A's	Either p or q. ——— Either not q or not p.	(For all x) either x is an A or x is a B. ——— (For all x) either x is not a B or x is not an A.
9. Particular inversion	If p, then q. Not p. ——— Not q.	(For all x) if x is an A, then x is a B. n is not an A. ——— n is not a B.	All A's are B's. n is not an A. ——— n is not a B.	Either p or q. p. ——— Not q.	(For all x) either x is an A or x is a B. n is an A. ——— n is not a B.
10. Full inversion	If p, then q. ——— If not p, then not q.	(For all x) if x is an A, then x is a B. ——— (For all x) if x is not an A, then x is not a B.	All A's are B's. ——— All non-A's are non-B's.	Either p or q. ——— Either not p or not q.	(For all x) either x is an A or x is a B. ——— (For all x) either x is not an A or x is not a B.

[a] "p", "q," and "r" stand for propositions. "x" is a variable term. "n" is a term referring to some particular thing. "A", "B," and "C" are class names or designators.

[b] The short horizontal line separates the premise(s) and the conclusion in each idealized argument form.

[c] Roberge has urged that "Either not p or q" be used here and elsewhere in this column (with a corresponding change in the other premise, if any), because "Either p or q" is logically equivalent to "If not p, then q," rather than "If p, then q." He has a significant point, but I chose to use "Either p or q" because that is the most natural form of alternation. If one wants, one can think of "p" in "Either p or q" as standing for "not p_1" in "Either not p_1 or q," which is equivalent to "If p_1, then q." Alternately, one can think of the "p" in "If p, then q" as "not p_1" in order to achieve a Roberge-suggested equivalence with "Either p_1 or q." Similar comments apply to "(For all x) either x is an A or x is a B." To save space, the clause "but perhaps both" is omitted from each alternation, except in the sixth row (a, b, c, and d) where the clause is inappropriate.

[d] To show parallelisms, biconditionality principles are grouped together.

Invalid Moves" in Part B, any argument adhering to these forms is invalid. The first column of the table gives the name of the principles; the second and third columns present standard elementary principles of conditional reasoning; the fourth column illustrates the principles of class logic and the last two columns show the principles of alternation logic[1].

As most of the studies in the area of propositional logic are focused on the conditional, there is a substantial amount of information which has been obtained concerning this operation. As in children, results of recent research on teenagers' ability to reason with conditional arguments (e.g., Berzonsky and Ondrako, 1974; Gardiner, 1966; Jansson, 1977; O'Brien, 1972; O'Brien, Shapiro and Realli, 1971; Roberge, 1970, 1976, 1978; Taplin, Standenmayer and Taddonio, 1974) have generally shown them to be more proficient with valid principles of inference than with invalid principles. In contrast, there is insufficient information concerning the growth of the other operations. The disjunctive, defined as any proposition which uses the logical connective "Either...or" is one of these.

Studies involving disjunctive arguments (e.g. Johnson-Laird and Tridgell, 1972; Roberge, 1974, 1976; Van Duyne, 1974) have been restricted to either the valid or the invalid principle but not both. Roberge (1977) predicted that arguments embodying an invalid principle of disjunction would be significantly more dif-

[1] In this paper, we have chosen to use the broader term "disjunctive logic" rather than "alternation logic".

ficult than those embodying a valid principle. His results supported this prediction, and is thus concordant with the findings of recent research on teenagers' ability to reason with conditional principles.

The content of the logical arguments is a factor which may influence the subjects' ability to draw valid inferences. For example, Long and Welch (1942) found with children (ages 8-11½ years old) as Wilkins (1928) and Sells (1936) had with adults, that "...the difficulty of applying a principle of reasoning increases as the meaningfulness of the term decreases". These findings have been reaffirmed in most studies dealing with conditonal arguments (e.g., Ennis and Paulus, 1968; Gardiner, 1966; Jansson, 1977; Roberge and Paulus, 1971). For the disjunctive arguments Van Duyne (1974) reported that adults found no difference between sentences involving concrete content, e.g., "A student doesn't study French or he is at London" and sentences involving abstract content, e.g., "A card doesn't have a P on one side or it has a 2 on the other side". Similar findings have been obtained by Roberge (1977) in a recent study.

In the present study, an attempt is made to investigate:

(i) teenagers' ability to master deductive arguments of four basic principles in conditional and disjunctive logic with two types of content; and

(ii) the influence of chronological age upon this ability.

A 48-item reasoning test was administered to 210 teenagers. On the basis of their educational status,

the subjects were classified into three groups: fourth formers, sixth formers and university students. There were 70 subjects in each group with equal numbers of males and females. The mean ages at these three groups were 14.95, 17.16 and 18.96 years respectively. The data were analysed using both the parametric analysis of variance and the non-parametric techniques.

Compared to conditional reasoning, the amount of information on teenagers' use of disjunctive reasoning is scarce. In conditional reasoning, the valid principles are easier to master than the invalid principles; and content of the logical argument is an important factor in the ability to draw valid conclusions. In disjunctive reasoning, the studies done with adults seem to indicate that the valid principles are also easier to master than the invalid principles; and content of the arguments is insignificant to the ability to draw valid inferences.

Given this information, it is expected that the valid principles would be easier to master than the invalid principles in both types of reasoning. It was also hypothesized that the ability to judge these deductive arguments would depend upon the subjects' chronological age as well as the content of the arguments.

Chapter two outlines the methodology employed in this study. Chapter three is divided into four sections, where Section A deals with the proportion of subjects who have mastered each of the four principles of conditional and disjunctive reasoning; Section B is made up of the parametric analysis of variance results; Section C is

concerned with the non-parametric treatment of the data and Section D consists of a summary of the previous sections. The final chapter contains a comparison of the results obtained from the present study with previous work in this area.

CHAPTER TWO

METHOD

In order to ascertain the amount of logical understanding in teenagers, a 48-item reasoning test was constructed. The construction and administration of the test are outlined below.

Subjects

One hundred and forty students from forms four and six were selected from two mixed schools in Christchurch. The students were chosen on the basis of their Progressive Achievement Test scores. Only the upper 50% of the students were selected. The mean ages of the students in the two forms were 14.95 and 17.16 years, respectively. In addition, 70 first-year university students were acquired on a voluntary basis from the University of Canterbury. The average age for this group of students was 18.96 years.

On the basis of their educational status, these teenagers were classified into three groups: fourth formers, sixth formers and university students. There were 70 subjects in each group with equal numbers of males and females.

Materials

A reasoning test consisting of 48 items was constructed. The reasoning test assessed the subjects' ability to master deductive arguments on four basic principles of conditional and disjunctive reasoning using two types of content.

(1) Types of principles

The four types of principle in conditional reasoning and its isomorphs in disjunctive reasoning were adapted from Ennis (1976). The principles included detachment, particular contraposition, particular conversion and particular inversion (see Table 3). These four principles are summarised and illustrated in Tables 4 and 5.

The first column gives the name of the principle, the second column indicates whether or not the form is valid as presented; the third column illustrates the symbolic form of the principle; and the fourth column gives a concrete example of the principle.

(2) Content

Two content categories were used: concrete and abstract.

Concrete content implies that vocabulary familiar to the subject is used; and further, that the truth value of the premises is empirically neutral. Abstract content, on the other hand, uses various combinations of geometrical coloured figures.

The two content categories are summarised and illustrated in Table 6. The first column identifies the content; the second column illustrates sample items for each content in conditional reasoning; and the third column shows sample items for each content category in disjunctive reasoning.

(3) Test-items

The item format was as follows:

Suppose you know

Premise number 1

TABLE 4: The four basic principles of conditional reasoning.

PRINCIPLE	VALIDITY	SYMBOLIC FORM	CONCRETE FORM
1. Detachment (Affirming the antecedent)	Yes	If p, then q p q	If the cat is black, then her name is Kitty. The cat is black The cat's name is Kitty
2. Particular Contrapositive (Denying the consequent)	Yes	If p, then q Not q Not p	If the car is black, then it is a police car. It is not a police car The car is not black
3. Particular Conversion (Affirming the consequent)	No	If p, then q q p	If the picture belongs to Susan, then it is a picture of a girl. It is a picture of a girl The picture belongs to Susan
4. Particular Inversion (Denying the antecedent)	No	If p, then q Not p Not q	If the car in the garage is Mr. Smith's, then it is white The car in the garage is not Mr. Smith's The car is not white

TABLE 5: The four basic principles of disjunctive reasoning.

PRINCIPLE	VALIDITY	SYMBOLIC FORM	CONCRETE FORM
1. Detachment	Yes	Either p or q (or both) Not p q	Either Don is tall or Don is thin (or Don is both tall and thin). Don is not tall. Don is thin.
2. Particular Contrapositive	Yes	Either p or q (or both) Not q p	Either the car is new or the car is white (or the car is both new and white). The car is not white. The car is new.
3. Particular Conversion	No	Either p or q (or both) q p	Either Peter is sick or Peter is lazy (or Peter is both sick and lazy). Peter is lazy. Peter is sick.
4. Particular Inversion	No	Either p or q (or both) p q	Either the house is old or the house is grey (or the house is both old and grey). The house is old. The house is grey.

TABLE 6: Examples of the content categories.

CONTENT CATEGORY	CONDITIONAL REASONING	DISJUNCTIVE REASONING
Concrete	If the cat is black, then her name is Kitty.	Either the cat is black or the cat is dirty (or the cat is both black and dirty).
Abstract	If the square is red, then the triangle is blue.	Either the square is red or the triangle is red (or both the square and the triangle are red).

Premise number 2

Then would this be true:

Conclusion.

The possible responses which the subject could make were: "Yes", "No" and "Maybe". The meanings of the possible answers were explained as follows:

Yes - The answer must be true,

No - The answer cannot be true,

Maybe - The answer may be true or may not be true. You were not told enough to be certain whether the answer is "Yes" or "No".

(4) Test-design

Six test-items were constructed for each of the four principles.

The overall test-design was divided into two parts, Part 1 consisting of 24 concrete items, where 12 were of the conditional type and the other 12 of the disjunctive type. Similarly, Part 2 consisted of 24 abstract items, again divided into 12 conditional and 12 disjunctive types. Thus, there was a total of 48 items in the complete test. A copy of the complete test is presented in Appendix I.

Procedure

At the two schools, the reasoning tests were administered separately for the fourth and the sixth formers. In both cases, the students were seated individually in their classrooms. The students were then told the general purpose of the exercise and were encouraged to inquire about anything they wanted to know.

The test booklets were handed out to the students. Instructions were then read out by the investigator. These are presented in Appendix 2. The students were given half an hour to complete the tests.

Similar procedures were carried out with the university students.

After the exercise, a few questions were posed by the investigator concerning the nature of the test. The general replies seemed to indicate:

(i) that subjects found no difference between the items presented in Part 1 and the items presented in Part 2, and

(ii) that subjects found the "Either...or" arguments easier to master than the "If...then" arguments.

CHAPTER THREE

RESULTS

The first section of this chapter is concerned with the proportion of subjects who have mastered the four basic principles of deductive reasoning. Since each principle subtest contains three items yielding a range from zero to three, mastery is defined as a correct score of three out of the three items. Following this discussion, the statistical analysis of the data will be presented. The data were analysed using both parametric and non-parametric statistics. The parametric analysis of variance was used although it is clear that the normality assumptions will not be completely fulfilled when a four-category dependent variable is used. However, the resulting tests of significance should still give useful estimates of the relative strengths of effects. As a check on the analysis of variance results, non-parametric analyses were carried out; the results of which are presented in the next section of the chapter.

A. PROPORTION OF SUBJECTS WHO HAVE MASTERED THE FOUR PRINCIPLES OF DEDUCTIVE REASONING.

The proportion of subjects who have mastered each of the four basic principles of deductive reasoning are shown in Table 7. The table indicates :

(i) Increasing mastery with age for the four principles in the two types of reasoning as well as within the two types of content;

(ii) Little difference in the proportion of subjects

TABLE 7: Proportion of subjects who have mastered the four basic principles of conditional and disjunctive reasoning in concrete and abstract content.

EDUCATIONAL LEVEL	CONTENT	CONDITIONAL REASONING				DISJUNCTIVE REASONING			
		Detachment	Particular Contraposition.	Particular Conversion	Particular Inversion	Detachment	Particular Contraposition.	Particular Conversion	Particular Inversion
Fourth formers (N = 70)	Concrete	.74	.24	.26	.17	.39	.37	.37	.37
	Abstract	.90	.31	.14	.30	.40	.39	.66	.56
Sixth formers (N = 70)	Concrete	.79	.36	.56	.31	.67	.66	.76	.71
	Abstract	.99	.59	.44	.49	.71	.63	.80	.80
University Students (N = 70)	Concrete	.93	.51	.56	.37	.89	.79	.91	.94
	Abstract	.90	.47	.47	.33	.91	.93	.96	.96

TABLE 8: Proportion of subjects who have mastered the principles of both conditional and disjunctive reasoning.

	PRINCIPLES			
EDUCATIONAL	Detachment	Particular Contraposition	Particular Conversion	Particular Inversion
Fourth Formers (N = 70)	0.17	0.03	0.04	0.00
Sixth Formers (N = 70)	0.50	0.13	0.26	0.26
University Students (N = 70)	0.69	0.26	0.33	0.20

mastering the principles in either the concrete or the abstract content;

(iii) With the exception of the detachment principle in conditional reasoning, there is a larger proportion of subjects mastering the principles in disjunctive reasoning than the principles in conditional reasoning;

(iv) In conditional reasoning (for both types of content), the proportion of subjects mastering the detachment principle is the largest, whereas the proportions of subjects mastering the other three principles are much lower;

(v) In disjunctive reasoning (for both types of content), the proportions of subjects mastering each of the invalid principles, conversion and inversion, are slightly larger than the proportions of subjects mastering each of the valid principles, detachment and contraposition. This holds in all instances, except with the fourth formers, for items in concrete content.

Table 8 presents the proportion of subjects who have mastered the four principles of both the conditional and the disjunctive reasoning. As can be seen from the table, only a small proportion of subjects have mastered these principles in the two types of reasoning.

It is instructive to compare the results obtained in this study with those of earlier studies. These previous researchers have listed only the results of deductive arguments in conditional reasoning with concrete content. Thus, we can only compare the results of the four principles of conditional reasoning with concrete content. These results are summarised in Table 9. As can be seen from

TABLE 9: Percentages of subjects who have mastered each of the four basic principles of deductive reasoning in conditional form (Roberge, 1972; Jansson, 1975, 1977).

EDUCATIONAL LEVEL	PRINCIPLES				n/N	RESEARCHER
	Detachment	Particular Contraposition	Particular Conversion	Particular Inversion		
4	53	35	2	2	8/12	Roberge (1970)
5	51	30	2	3	5/6	Ennis & Paulus (1965)
4 - 5	59	16	0	2	5/6	Gardiner (1965)
6	54	23	0	0	8/12	Roberge
7	56	41	3	6	5/6	Ennis & Paulus
6 - 7	79	23	0	2	5/6	Gardiner
8	95	74	0	0	8/12	Roberge
8	71	43	1	6	6/8	Jansson (1977)
9	66	35	4	5	5/6	Ennis & Paulus
8 - 9	89	48	4	4	5/6	Gardiner
10	100	65	19	5	8/12	Roberge
10	76	53	3	5	6/8	Jansson
10	74	24	26	17	3/3	Mohd. Noor
11	62	35	3	12	5/6	Ennis & Paulus
11 - 12	99	47	30	20	5/6	Gardiner
12	93	44	6	19	6/8	Jansson
12	79	36	56	31	3/3	Mohd. Noor
Pre-Service Elementary School Teachers	84	31	11	21	6/8	Jansson (1975)
University Students	93	51	56	37	3/3	Mohd. Noor

n = number of items required for mastery of a principle N = total number of items for a principle

the table, the detachment principle is by far the easiest. The results of the earlier studies also indicate that the contraposition principle is relatively easier than the two invalid principles, conversion and inversion. In contrast, our results show that the contraposition principle is just as difficult as the invalid principles, conversion and inversion.

B. ANALYSIS OF VARIANCE

A 3 x 2 x 2 x 2 x 4 (Educational level by sex by type of content by type of reasoning by type of principle) factorial design, with repeated measures on the last three factors, was used. The analysis of variance results are presented in Table 10. Cross-tabulations of the significant two-way interactions are given in Table 11.

There is a significant ($p < .01$) improvement with age as students move from the fourth form level to the university level (Table 10). This improvement can be seen in Figure 1.

FIGURE 1: Percentage of correct responses at the three educational levels.

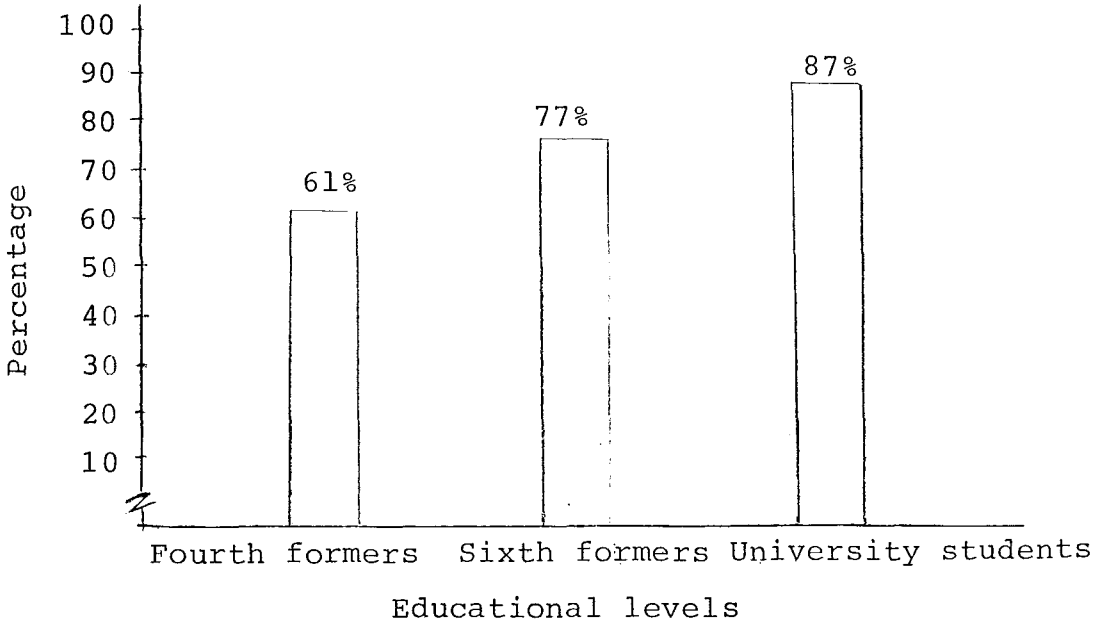


TABLE 10: Results of the analysis of variance for educational levels, sex, type of content, type of reasoning and type of principle.

SOURCE	df	MS	F
Between Subjects			
G (Educational level)	2	180.98	52.56**
X (Sex)	1	3.87	1.12
G x X	2	1.65	.48
Subjects within groups	204	3.44	
Within Subjects			
C (Type of content)	1	2.30	3.26
G x C	2	.04	.05
X x C	1	.08	.11
G x X x C	2	.19	.26
C x Subjects within groups	204	.71	
R (Type of reasoning)	1	92.67	55.90**
G x R	2	8.06	4.86*
X x R	1	6.34	3.83
G x X x R	2	.09	.05
R x Subjects within groups	204	1.66	
P (Type of principle)	3	49.39	64.07**
G x P	6	2.98	3.87**
X x P	3	.46	.60
G x X x P	6	.63	.82
P x Subjects within groups	612	.77	
C x R	1	11.43	19.74**
G x C x R	2	.81	1.40
X x C x R	1	1.54	2.66
G x X x C x R	2	.39	.67
C x R x Subjects within groups	204	.58	
C x P	3	2.90	6.41**
G x C x P	6	.75	1.65
X x C x P	3	1.07	2.37
G x X x C x P	6	.19	.43
C x P x Subjects within groups	612	.45	
R x P	3	68.81	91.71**
G x R x P	6	4.31	5.75**
X x R x P	3	1.32	1.76
G x X x R x P	6	.60	.80
R x P x Subjects within groups	612	.75	
C x R x P	3	6.91	14.70**
G x C x R x P	6	.95	2.03
X x C x R x P	3	.28	.59
G x X x C x R x P	6	.35	.74
C x R x P x Subjects within groups	612	.47	

** $p < .01$
* $p < .05$

TABLE 11: Cross-tabulations of the significant two-way interactions from the analysis of variance results.

	TYPE OF REASONING	
	Conditional	Disjunctive
EDUCATIONAL LEVEL		
Fourth formers	1.73	1.91
Sixth formers	2.15	2.46
University students	2.36	2.88

	TYPE OF REASONING	
	Conditional	Disjunctive
CONTENT		
Concrete	2.17	2.38
Abstract	2.00	2.45

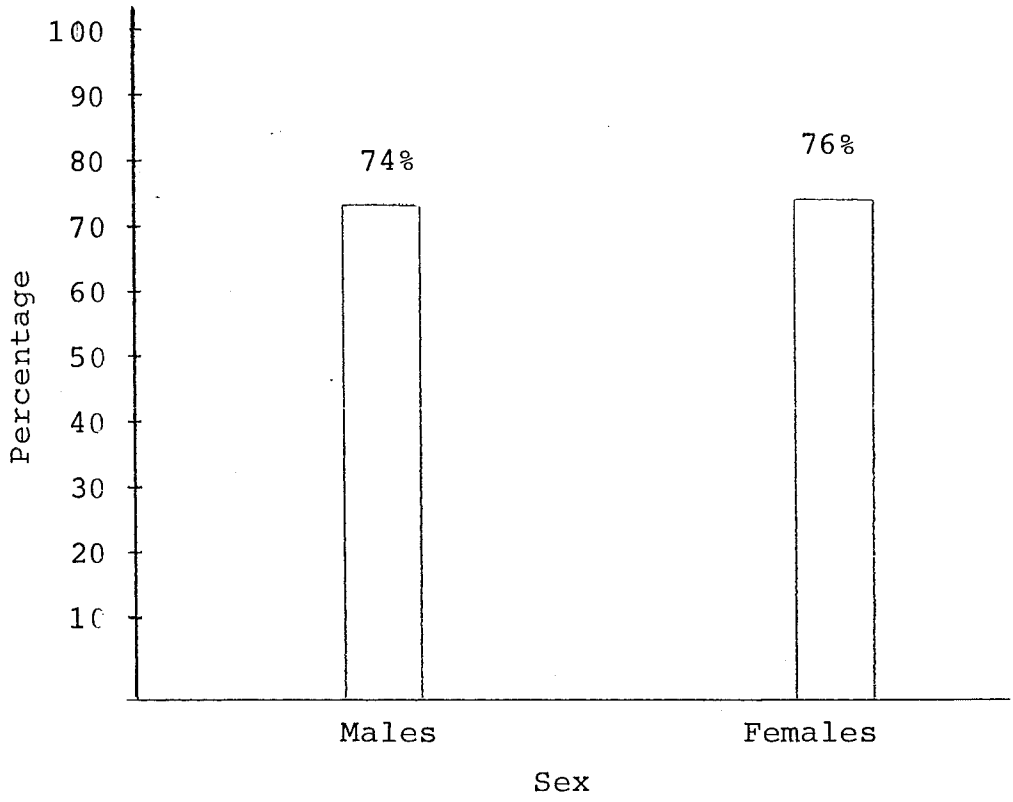
	TYPE OF PRINCIPLE			
	Detachment	Contraposition	Conversion	Inversion
EDUCATIONAL LEVEL.				
Fourth form.	2.30	1.71	1.55	1.73
Sixth form.	2.64	2.22	2.25	2.11
University	2.89	2.57	2.57	2.45

	TYPE OF PRINCIPLE			
	Detachment	Contraposition	Conversion	Inversion
CONTENT				
Concrete	2.57	2.21	2.22	2.09
Abstract	2.65	2.12	2.02	2.10

	TYPE OF PRINCIPLE			
	Detachment	Contraposition	Conversion	Inversion
TYPE OF REASONING				
Conditional	2.85	1.99	1.79	1.70
Disjunctive	2.37	2.34	2.46	2.49

There is no significant difference between the scores of the males and the scores of the females (Table 10). This can be seen in Figure 2.

FIGURE 2: Percentage of correct responses for the two sexes



There is no significant difference between items embedded in the concrete content and items embedded in the abstract content (Table 10). This can be seen in Figure 3.

There is a significant ($p < .01$) difference between conditional reasoning and disjunctive reasoning (Table 10). This difference can be seen in Figure 4.

The 'type of reasoning by educational level' interaction effect is significant ($p < .01$). In Table 11, it is apparent that the difference is most pronounced at the university level, where the disjunctive reasoning is much easier than the conditional reasoning. This difference is illustrated in Figure 5.

FIGURE 3: Percentage of correct responses for the two types of content.

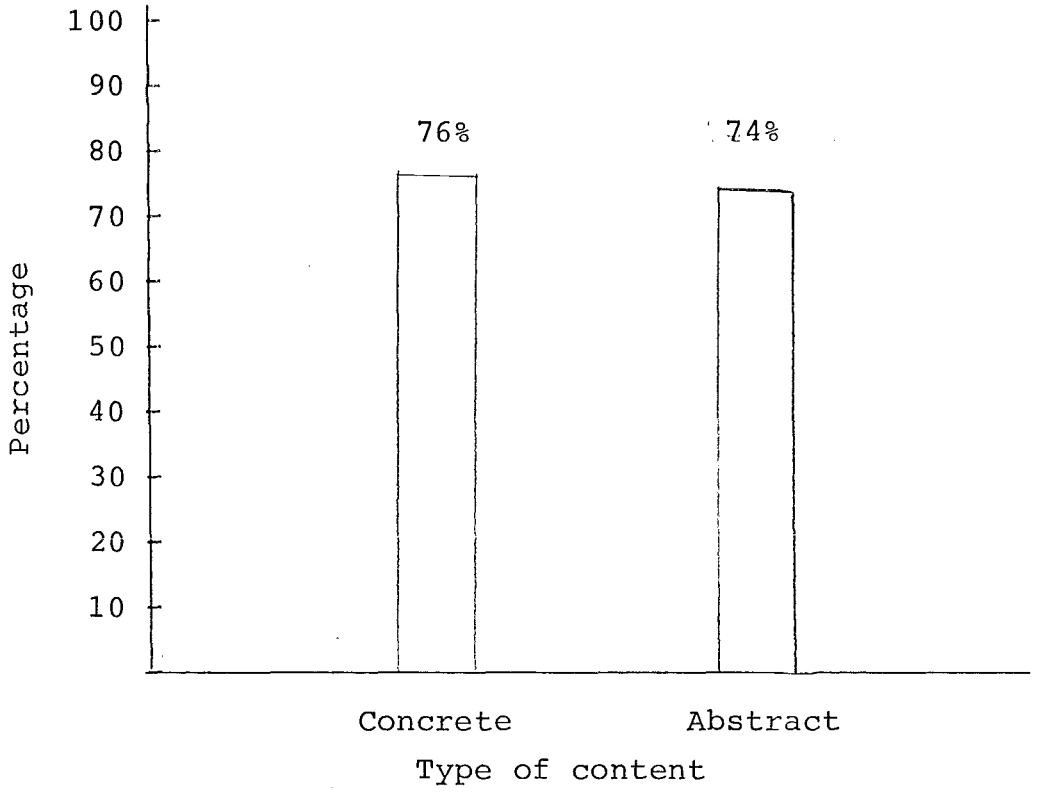


FIGURE 4: Percentage of correct responses for the two types of reasoning.

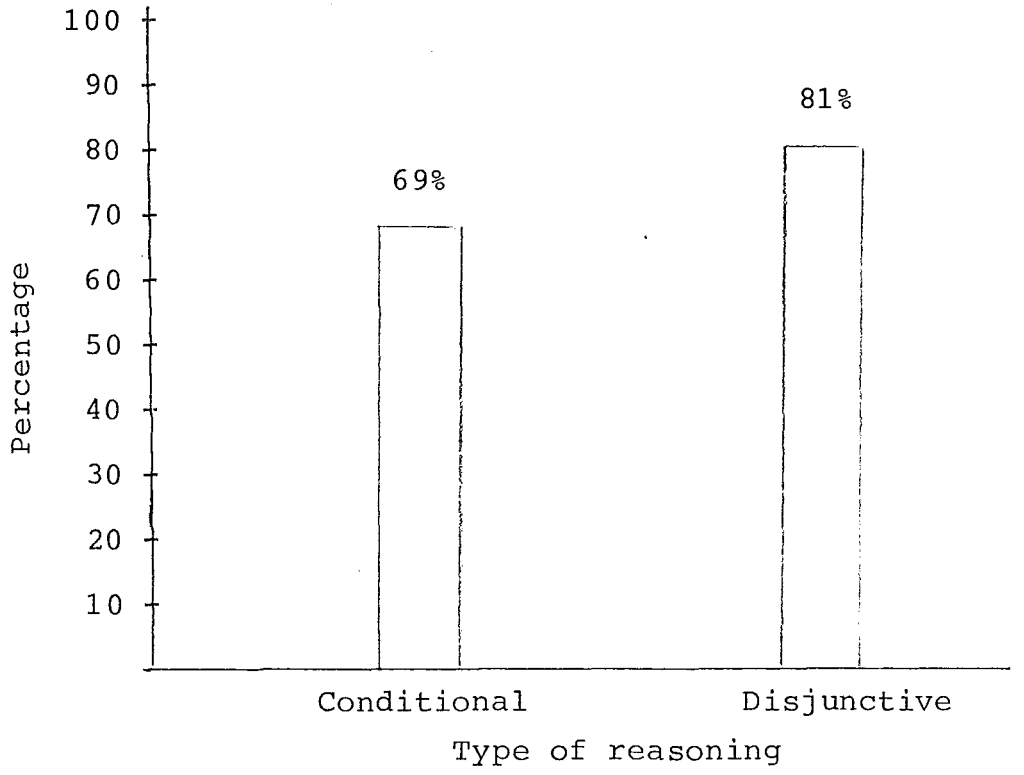
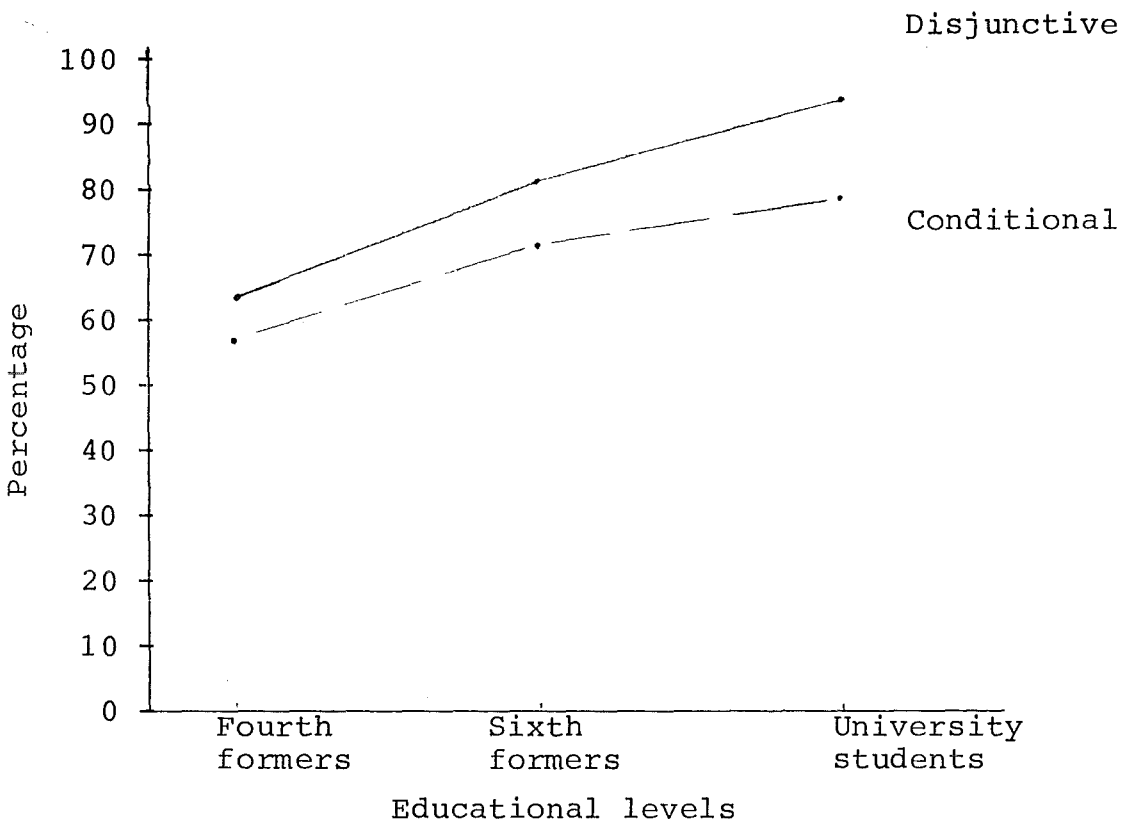


FIGURE 5: Percentage of correct responses for the 'type of reasoning by educational level' interaction.



The 'type of reasoning by type of content' interaction effect is also significant ($p < .01$). In Table 11, it can be seen that the difference occurs mainly with the abstract content, where the disjunctive reasoning is again easier than the conditional reasoning. This difference is illustrated in Figure 6.

There is a significant ($p < .01$) difference between the four types of principles (Table 10). As can be seen in Figure 7, this is due to the difference between the detachment principle and the other three principles.

The 'type of principle by educational level' interaction effect is significant ($p < .01$). Table 11 shows that this difference occurs at all the three educational levels between the detachment principle and the other three principles. Figure 8 illustrates this interaction.

FIGURE 6: Percentage of correct responses for the 'type of reasoning by type of content' interaction.

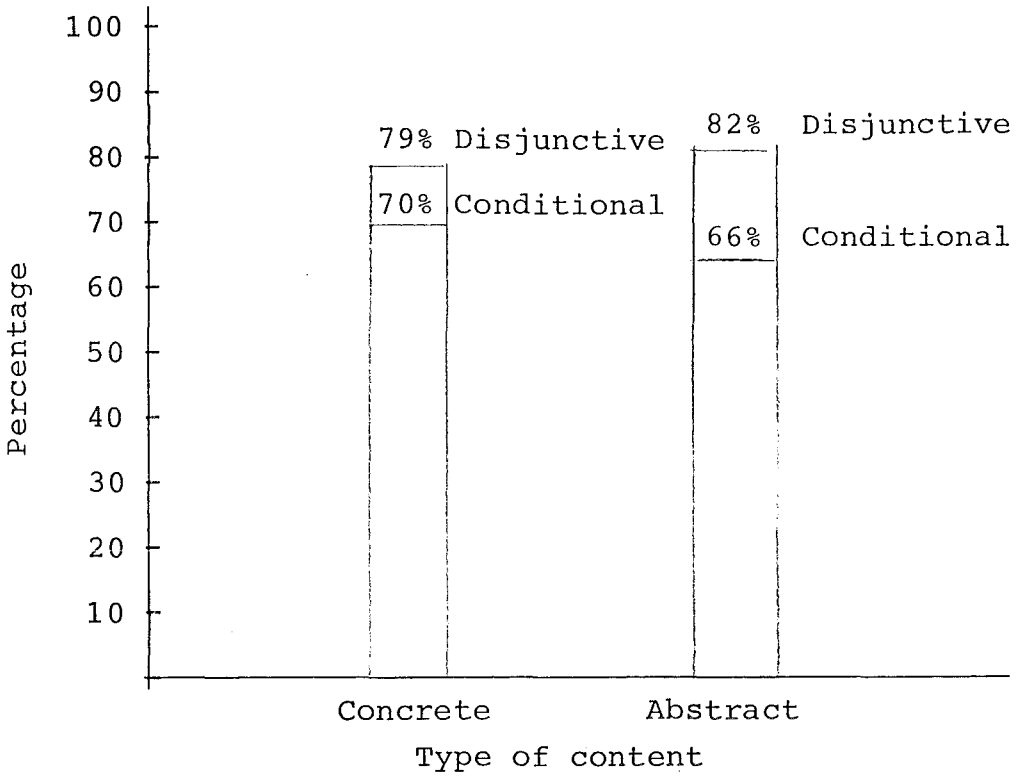


FIGURE 7: Percentage of correct responses for the four types of principle.

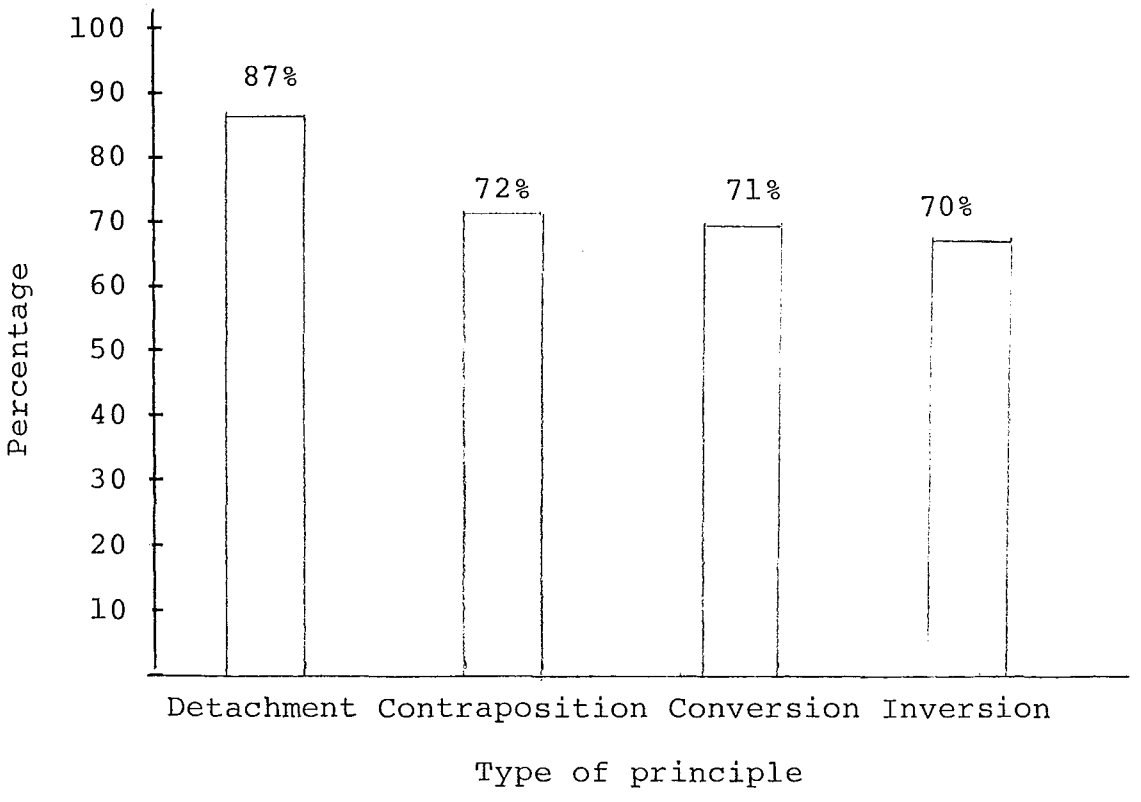
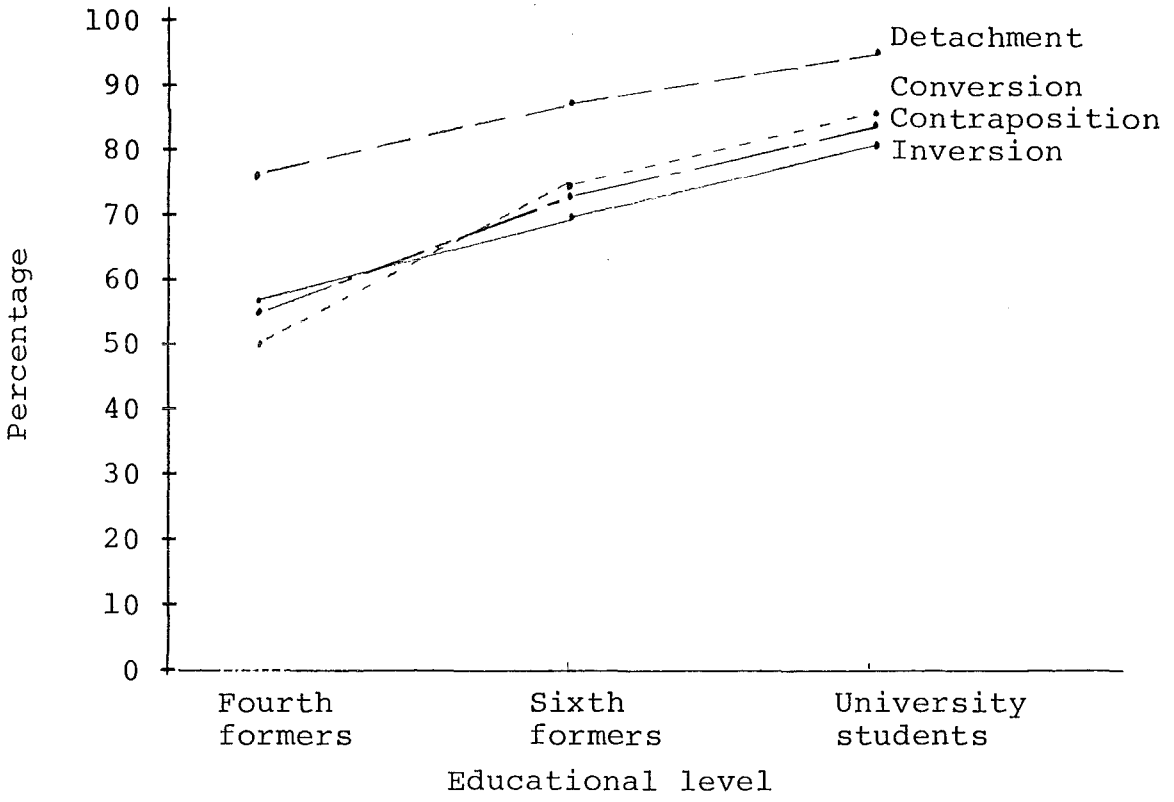


FIGURE 8: Percentage of correct responses for the 'type of principle x educational level' interaction.



The 'type of principle by type of content' interaction effect is also significant ($p < .01$). Table 11 shows that this interaction is due to the detachment principle and the other three principles in both types of content. Figure 9 illustrates this interaction.

Table 10 also shows a significant ($p < .01$) 'type of principle by type of reasoning' interaction effect. In Table 11, it is apparent that this difference occurs with the conditional reasoning, where the detachment principle is much easier than the other three principles. This difference is illustrated in Figure 10.

The 'educational level by type of reasoning by type of principle' interaction effect is significant ($p < .01$). The cross-tabulations of this interaction can be seen in Table 12. The table shows that for conditional reasoning, there are differences between the detachment principle and the

and the other three principles. In contrast, there are no differences between the four principles of disjunctive reasoning. The differences occur at each of the three educational levels. Figures 11a and 11b illustrate this interaction.

FIGURE 9: Percentage of correct responses for the 'type of principle by type of content' interaction.

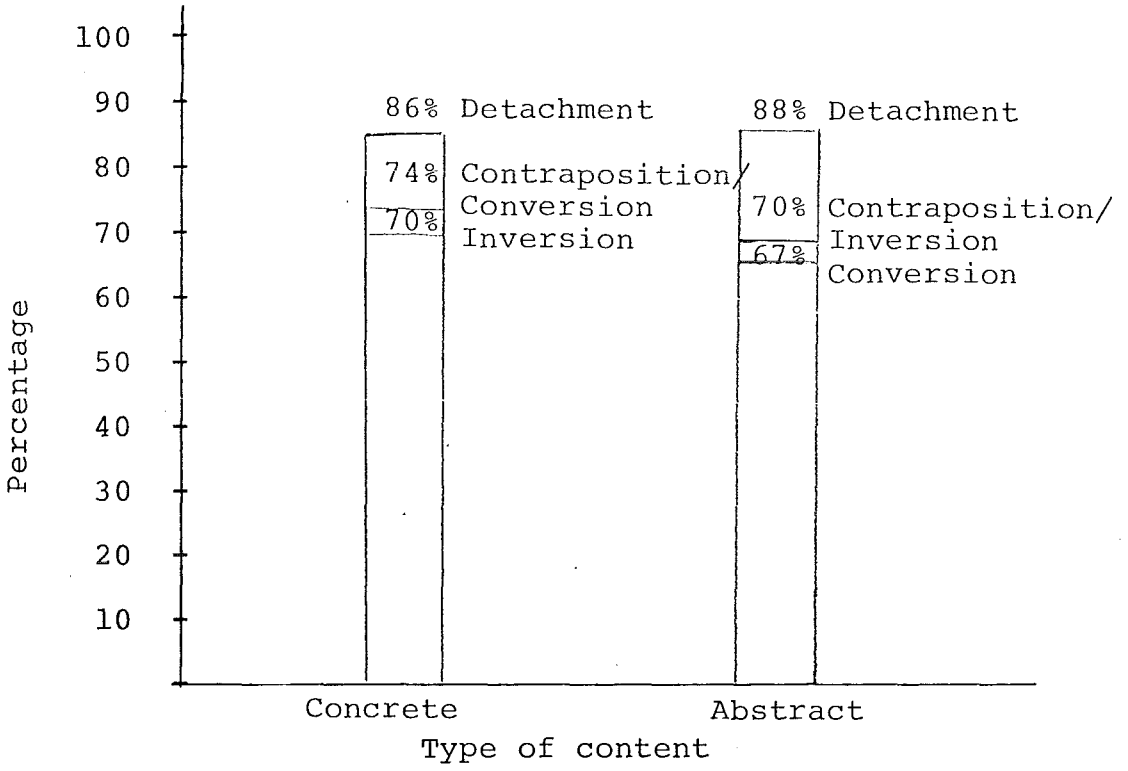


FIGURE 10: Percentage of correct responses for the 'type of principle by type of reasoning' interaction.

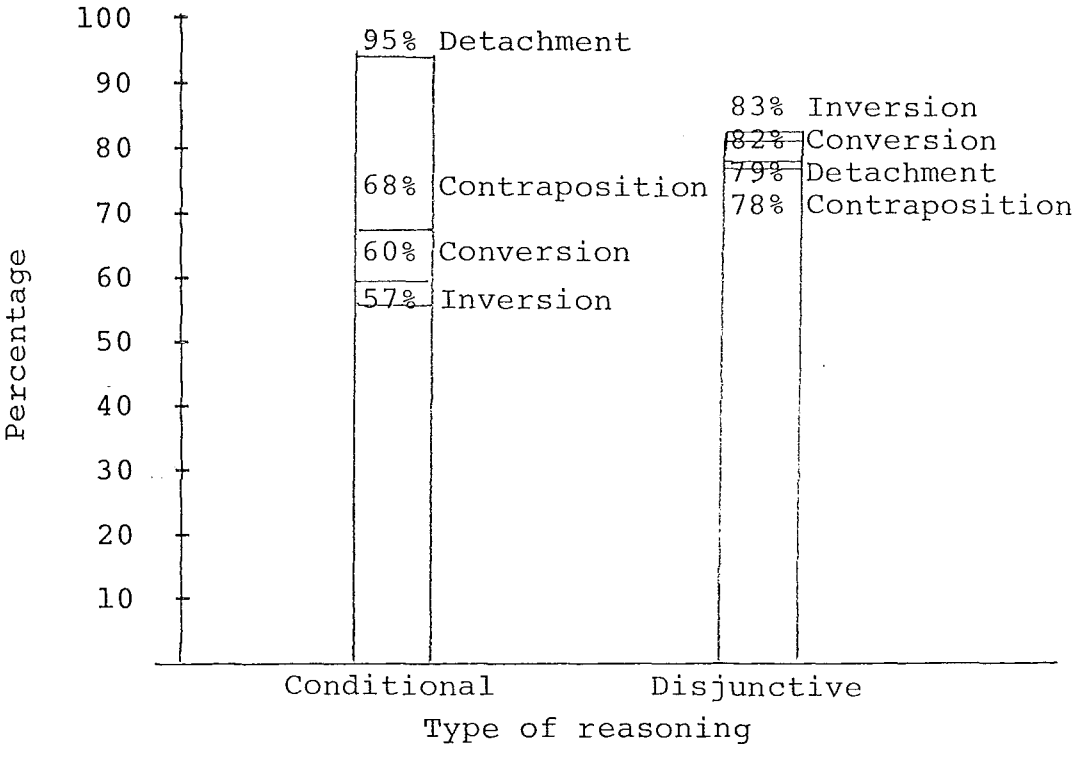
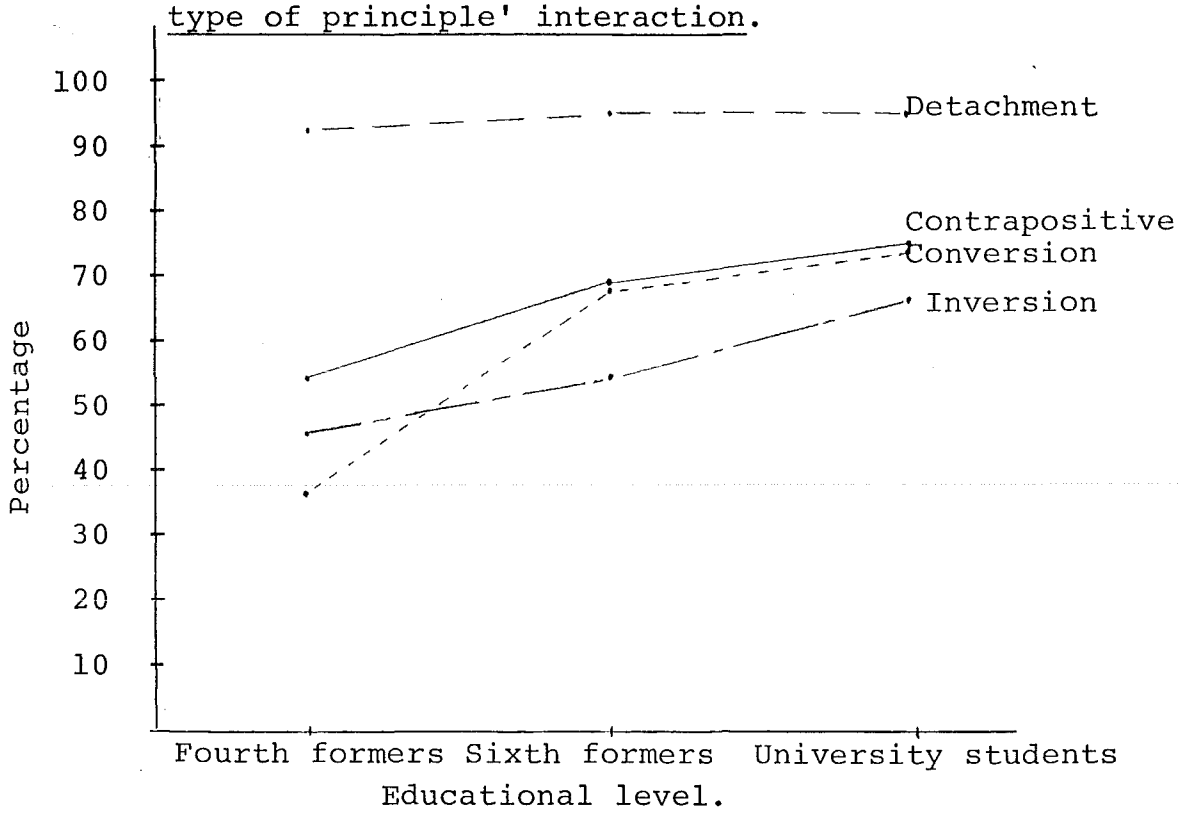


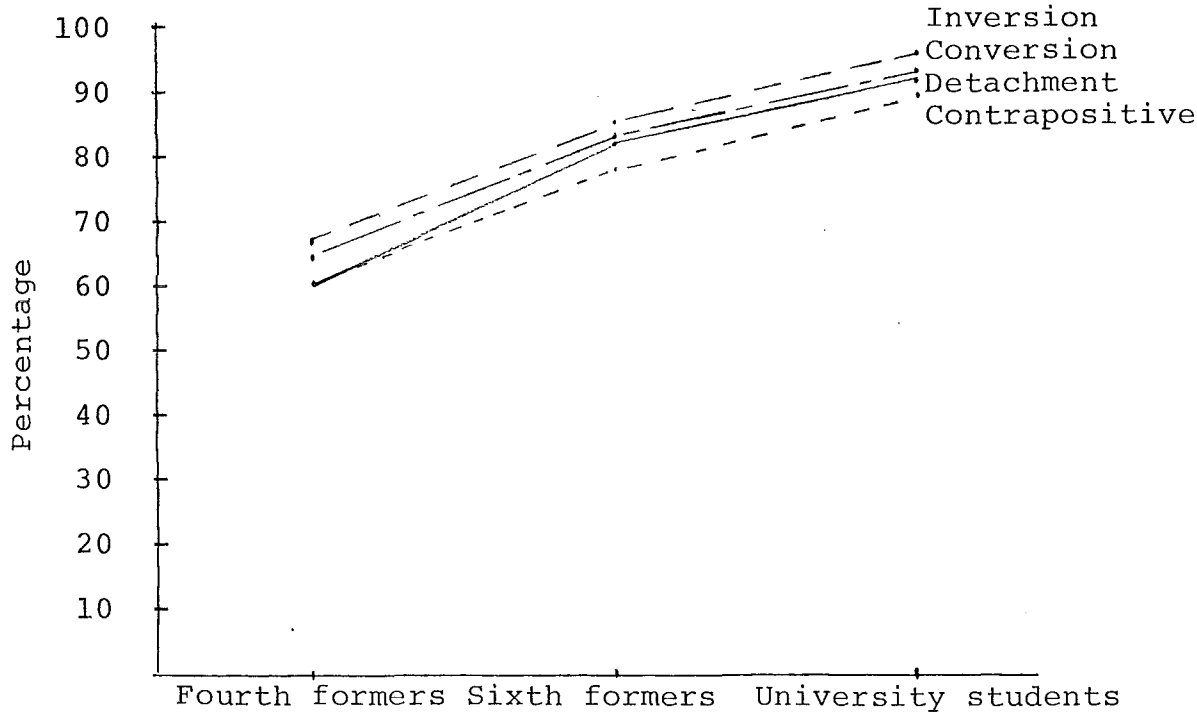
TABLE 12: Cross-tabulations of the 'educational level by type of reasoning by type of principle' interaction.

EDUCATIONAL LEVEL	TYPE OF REASONING	PRINCIPLE			
		Detachment	Particular Contraposition	Particular Conversion	Particular Inversion
Fourth formers	Conditional	2.78	1.59	1.11	1.44
	Disjunctive	1.82	1.82	1.98	2.02
Sixth formers	Conditional	2.86	2.06	2.00	1.69
	Disjunctive	2.41	2.38	2.50	2.53
University students	Conditional	2.91	2.31	2.25	1.97
	Disjunctive	2.87	2.82	2.89	2.92

FIGURE 11: Percentage of correct responses for the 'educational level by type of reasoning by type of principle' interaction.



(a) Conditional Reasoning



(b) Disjunctive Reasoning

Finally, Table 10 indicates a significant ($p < .01$) 'type of content by type of reasoning by type of principle' interaction effect. The cross-tabulations of this interaction are given by Table 13. From the table, it can be seen that the results obtained in both types of content are similar, i.e., there are differences between the detachment principle and the other three principles in conditional reasoning, whereas the four principles in disjunctive reasoning are similar. Figures 12a and 12b illustrate these differences.

C. NON-PARAMETRIC ANALYSES

As a check on the parametric analysis of variance results, non-parametric analyses were carried out. The reference for the various non-parametric statistics used in this section is the book by Marascuilo and McSweeney (1977).

(1) Educational Levels

Using the Kruskall-Wallis test, a significant ($p < .05$) difference is obtained for the subjects' total scores at the three educational levels. As the null hypothesis of identical distributions for the scores is rejected, possible reasons for this rejection must be examined from a post hoc point of view. As there is approximately a two-year gap between one educational level and the next, a trend analysis is carried out. The results of this analysis are summarised in Table 14. From the table, it is clear that there is a monotonic or linear relationship between subjects' total scores and their respective educational levels. Inspection of the ranked means at these three levels indicates that the relationship is monotonically increasing.

TABLE 13: Cross-tabulations of the 'type of content x type of reasoning x type of principle' interaction.

CONTENT	TYPE OF REASONING	PRINCIPLE			
		Detachment	Particular Contrapositive	Particular Conversion	Particular Inversion
Concrete	Conditional	2.78	2.07	2.07	1.76
	Disjunctive	2.37	2.35	2.38	2.43
Abstract	Conditional	2.92	1.91	1.51	1.65
	Disjunctive	2.37	2.33	2.54	2.55

FIGURE 12: Percentage of correct responses for the 'type of content by type of reasoning by type of principle' interaction.

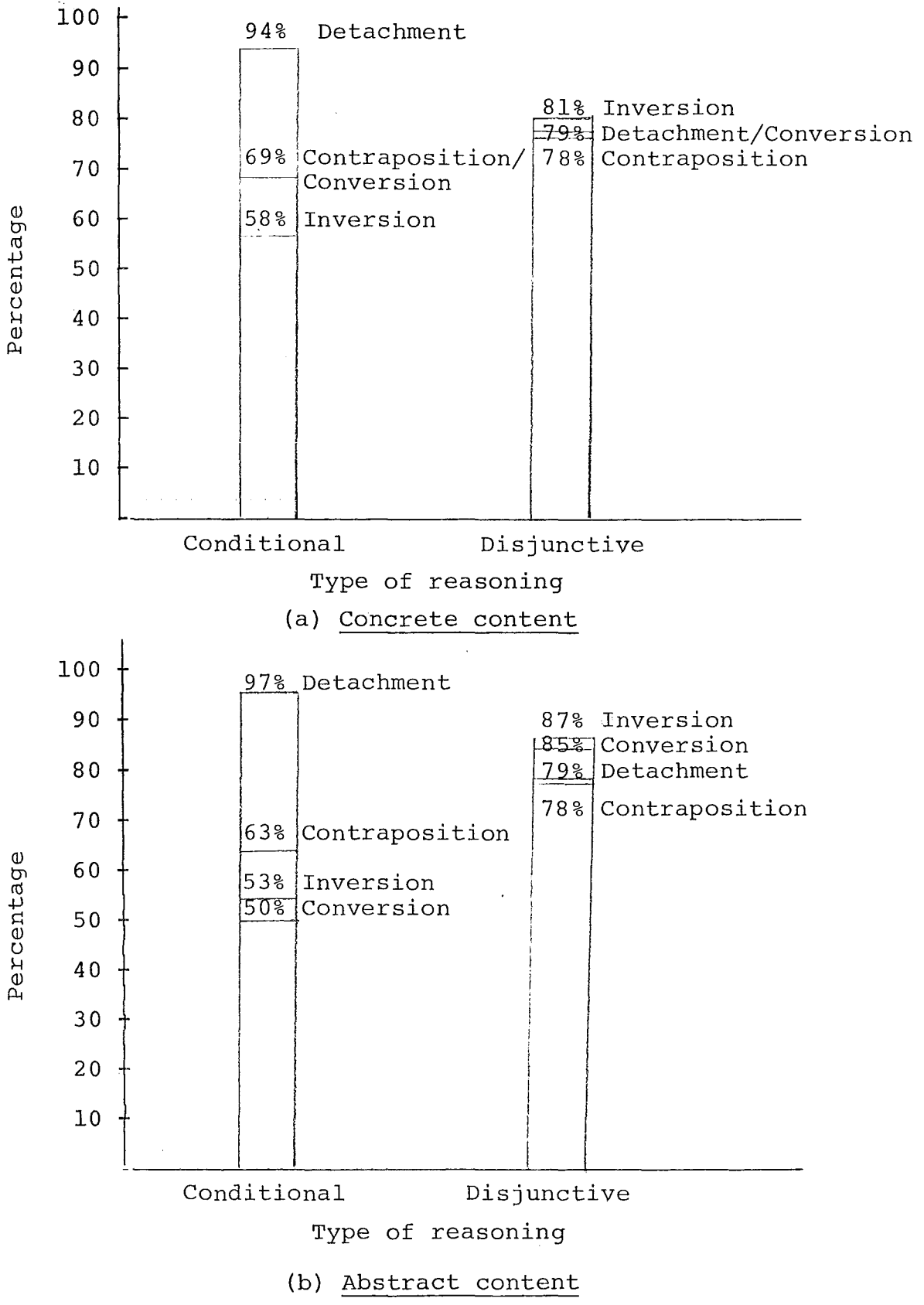


TABLE 14: Partitioning of the Kruskall-Wallis statistic in tests for monotonic trend.

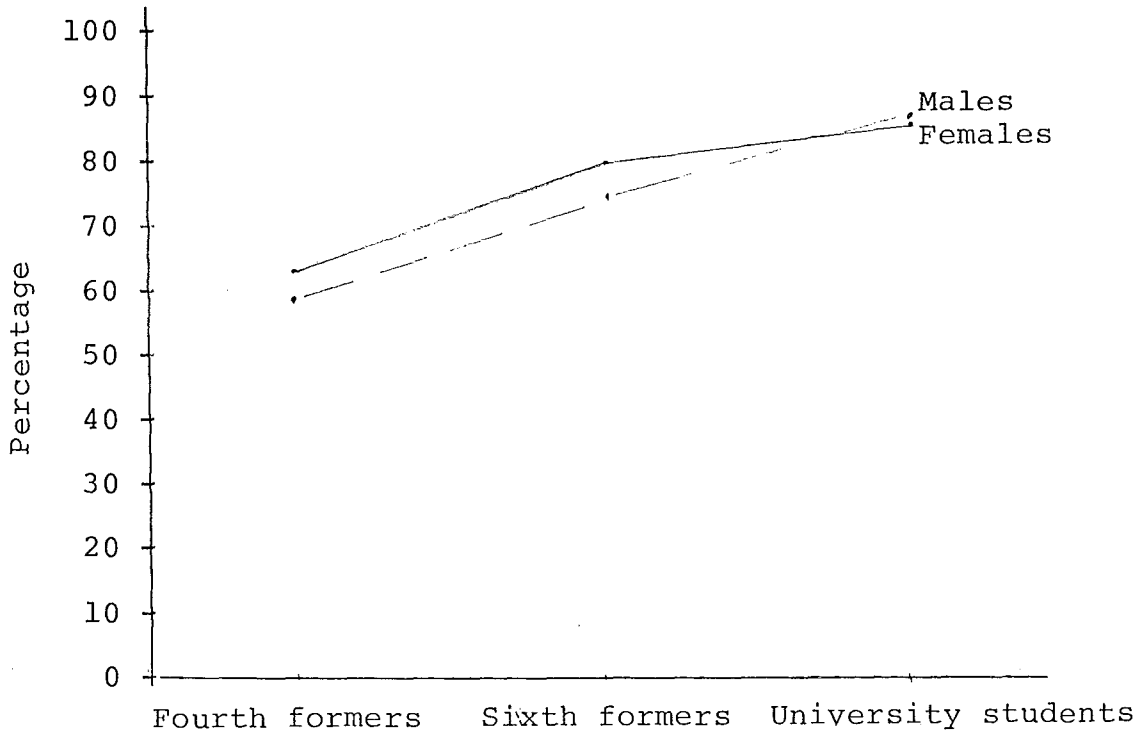
SOURCE	DEGREE OF FREEDOM	VALUE OF χ^2
Monotonic trend	1	70.89
Residual	2	.50
Total	3	71.39

	FOURTH FORMERS	SIXTH FORMERS	UNIVERSITY STUDENTS
Ranked means	60.05	109.56	146.53

(2) Sex Differences

Using the Mann-Whitney test, no significant differences are obtained between the scores of the males and the scores of the females at each of the three educational levels. This can be seen in Figure 13.

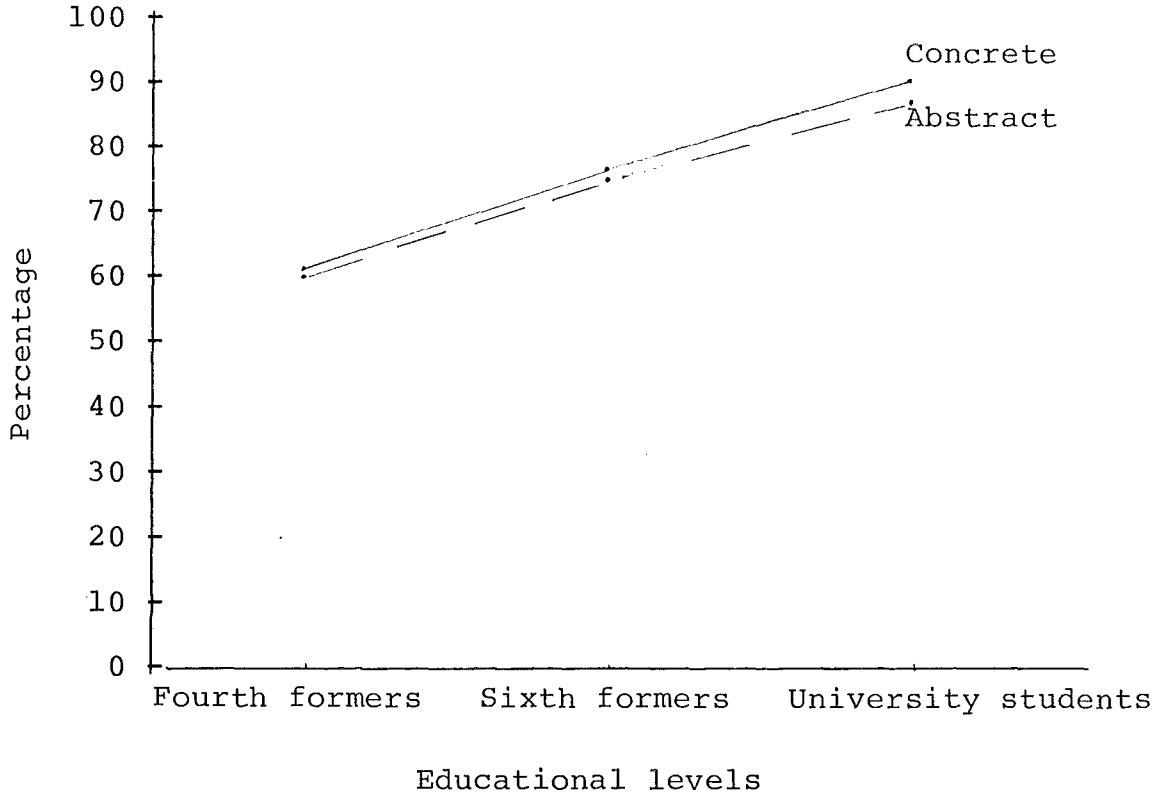
FIGURE 13: Percentage of correct responses for the males and the females at each of the three educational levels.



(3) Type of Content

Using the Friedman test, no significant differences are obtained between the two types of content at each of the three educational levels. This can be seen in Figure 14.

FIGURE 14: Percentage of correct responses for items in concrete and abstract content at each of the three educational levels.



(4) Type of Reasoning

The two types of reasoning are repeated within both the concrete and the abstract content. Using the Friedman test, the reasoning data are separately analysed within the concrete and the abstract content. Table 15 summarises the findings at each of the three educational levels. As can be seen from the table, all differences between the two types of reasoning are significant ($p < .05$), except for the difference between the two types of reasoning within the concrete content

TABLE 15: Differences between the two types of reasoning within the two types of content at each of the three educational levels.

EDUCATIONAL LEVEL	CONTENT		TYPE OF REASONING		DECISION*
			Conditional	Disjunctive	
Fourth formers	Concrete	Ranked sum	110	100	
		Ranked mean	1.57	1.43	Not significant
	Abstract	Ranked sum	116	94	
		Ranked mean	1.66	1.34	Significant
Sixth formers	Concrete	Ranked sum	119.5	90.5	
		Ranked mean	1.71	1.29	Significant
	Abstract	Ranked sum	116	94	
		Ranked mean	1.66	1.34	Significant
University students	Concrete	Ranked sum	127.5	82.5	
		Ranked mean	1.82	1.18	Significant
	Abstract	Ranked sum	128.5	81.5	
		Ranked mean	1.84	1.16	Significant

* Significant at $p < .05$

at the fourth form level. Table 15 also gives the ranked sums and means of the two types of reasoning within each type of content. In all instances, disjunctive reasoning obtains smaller values than conditional reasoning, indicating that it is easier to comprehend than conditional reasoning.

(5) Type of Principle

The four types of principles are repeated within the two types of content as well as within the two types of reasoning. As there are differences between the two types of reasoning, it is necessary to separate the four principles of conditional reasoning from the four principles of disjunctive reasoning. The resulting data are then analysed by the Friedman test.

For the four principles of conditional reasoning, significant ($p < .05$) differences are obtained between them at each of the three educational levels. Since the null hypothesis of identical distributions for the four types of principle is rejected, possible reasons for the rejection may be explained by means of post hoc comparisons on contrasts involving the ranked values. The six possible pairwise comparisons at each of the three educational levels are summarised in Table 16. It is apparent from the table that the detachment principle is different from the other three principles, contraposition, conversion and inversion. In addition, there are no differences between contraposition, conversion and inversion.

As for the four principles of disjunctive reasoning, no significant differences are obtained between them at each of the three educational levels.

TABLE 16: Results of the pairwise comparisons between the four principles in conditional reasoning at each of the three educational levels.

EDUCATIONAL LEVEL	COMPARISON (ψ)	VALUE OF COMPARISON	DECISION *
Fourth formers	ψ_1 = R detach. - R contrap.	1.21 - 2.76 = -1.55	significant
	ψ_2 = $\bar{R}$ detach. - $\bar{R}$ conver.	1.21 - 3.19 = -1.98	significant
	ψ_3 = $\bar{R}$ detach. - $\bar{R}$ inver.	1.21 - 2.80 = -1.59	significant
	ψ_4 = $\bar{R}$ contrap. - $\bar{R}$ conver.	2.76 - 3.19 = - .43	not significant
	ψ_5 = $\bar{R}$ contrap. - $\bar{R}$ inver.	2.76 - 2.80 = - .04	not significant
	ψ_6 = $\bar{R}$ conver. - $\bar{R}$ inver.	3.19 - 2.80 = + .39	not significant
Sixth formers	ψ_1 = $\bar{R}$ detach. - $\bar{R}$ contrap.	1.55 - 2.71 = -1.16	significant
	ψ_2 = $\bar{R}$ detach. - $\bar{R}$ conver.	1.55 - 2.67 = -1.12	significant
	ψ_3 = $\bar{R}$ detach. - $\bar{R}$ inver.	1.55 - 3.06 = -1.51	significant
	ψ_4 = $\bar{R}$ contrap. - $\bar{R}$ conver.	2.71 - 2.67 = + .04	not significant
	ψ_5 = $\bar{R}$ contrap. - $\bar{R}$ inver.	2.71 - 3.06 = - .35	not significant
	ψ_6 = $\bar{R}$ conver. - $\bar{R}$ inver.	2.67 - 3.06 = - .39	not significant
University students	ψ_1 = $\bar{R}$ detach. - $\bar{R}$ contrap.	1.56 - 2.59 = -1.03	significant
	ψ_2 = $\bar{R}$ detach. - $\bar{R}$ conver.	1.56 - 2.68 = -1.12	significant
	ψ_3 = $\bar{R}$ detach. - $\bar{R}$ inver.	1.56 - 3.19 = -1.63	significant
	ψ_4 = $\bar{R}$ contrap. - $\bar{R}$ conver.	2.59 - 2.68 = - .09	not significant
	ψ_5 = $\bar{R}$ contrap. - $\bar{R}$ inver.	2.59 - 3.19 = - .60	not significant
	ψ_6 = $\bar{R}$ conver. - $\bar{R}$ inver.	2.68 - 3.19 = - .31	not significant

* Any difference >.61 is significant at $p < .05$

D. SUMMARY

As the normality assumptions of the parametric analysis of variance are not completely fulfilled, the results cannot be taken as totally valid. Certain non-parametric analyses are carried out. These non-parametric analyses serve as checks on the analysis of variance results as well as providing a separate technique of analysing the data without making any underlying assumptions, as was the case in the analysis of variance. From the previous section, it can be seen that the results of the non-parametric analyses are highly similar to those of the parametric analysis of variance. Thus, even though the normality assumptions of the parametric analysis of variance are not completely fulfilled, the resulting parametric tests of significance still yield estimates that are informative and useful.

The results of both analyses indicate that mastery of the four basic principles of deductive logic improves with age. Further, the results indicate no difference between the two sexes relative to their performance on the reasoning test. The results also indicate that subjects find no difference in difficulty between items within the concrete content and items within the abstract content. The results also show that there are differences between subjects' mastery of the detachment principle and the other three principles of conditional reasoning. By contrast, there is no difference between subjects' mastery of the four principles in disjunctive reasoning. Finally, the results show that subjects find items in disjunctive reasoning easier to master than items in conditional reasoning.

CHAPTER FOUR

DISCUSSION

In the present study, we have examined teenagers' ability to master deductive arguments. These arguments are based on four basic principles of conditional and disjunctive reasoning, with two types of content.

The results obtained have replicated the previously established finding (e.g., Roberge and Paulus, 1971; Jansson, 1977) that performance on conditional reasoning tasks shows a general improvement with age. This finding may be considered to indicate that conditional reasoning becomes more logical with age. However, an equally possible conclusion to draw would be that the meaning of the conditional has changed with age, and that reasoning at all ages is logical.

Taplin et al (1974) considers the second possibility as being more likely. According to him, the nature of this change for the conditional is as follows:

> "...juxtaposition in its most primitive form appears to refer to conjunctive connectives between events. With increasing age, however, this interpretation is superceded by a biconditional or equivalence relation between events. In effect, the bond between the events has become such that not only do they occur together, but also whenever one is absent, the other is absent too. With further development this interpretation may be modified again until, in addition to the preceding meanings, the second event may sometimes occur in the absence of the first, although

the first may not occur without the second." (pg. 371)

Thus he concludes

> "It is not that college students are necessarily more logical than third-grade pupils, but that they have a different understanding of the meaning of the premises."

The present study shows that within the age range studied, both alternatives are possible. However, these two alternatives are not contradictory to one another. In fact they complement each other. Within this context, Taplin's (1974) explanations show how the subjects have become more logical with age, i.e., they have become more logical with age because their understanding of the meaning of the conditional premises has changed with age. As Henle (1962) states

> "...If individuals naive about specifications in propositional logic do not interpret 'if...then' according to the conditional classification, it is not valid to conclude that their reasoning is in error. They are illogical only in the sense that they do not interpret the 'if...then' connective according to one unique specification which from a psychological point of view, is arbitrary. When reasoning 'if p then q' is evaluated according to the interpretation each individual gives to the sentence, the inference may be perfectly consistent and logical with respect to that interpretation." (pg. 374)

The same explanations can also be applied to disjunctive reasoning. It is feasible that there is a change in subjects' understanding of the meaning of the "either...or" connective with age, indicating that they have become more logical.

From the results of the present study, it can be seen that the factor sex and its interactions with the other four factors are not significant. These findings are consistent

with those reported in previous studies (e.g. Ennis, 1971; O'Brien and Shapiro, 1968; Roberge, 1970, 1978).

Further, the results show that subjects reason equally well with items embedded in the concrete and abstract content. For disjunctive arguments, this finding is consistent with those reported in earlier studies (e.g. Van Duyne, 1974; Roberge, 1977). However, for conditional arguments, this finding is not consistent with those of previous studies (e.g. Johnson-Laird, Legrenzi and Legrenzi, 1972; Wason, 1968; Wason and Johnson-Laird, 1972). A possible explanation for the discrepant findings is suggested by the nature of the tasks used in these studies. That is, in the present study the subjects were presented with a pair of premises and were asked to construct the conclusion that followed logically from these premises. In contrast, Wason and his followers used a problem-solving situation in which the subjects were shown four cards (or envelopes) and were asked to select the cards (or envelopes) needed to determine whether a given logical rule was true (or false). In other words, the inconsistent findings for these studies suggest that the type of content that is most beneficial in a given problem-solving situation varies according to the novelty of the task and the task demands.

The results also show that subjects' mastery of items in disjunctive reasoning is much larger than those in conditional reasoning. This greater difficulty with the latter may be due to the fact that with conditional reasoning, the subject must consider not only the form of the statements but also their order. Further, the subject must determine

not only whether the conclusion follows from the premises but also whether it is the only conclusion that can follow. The difficulties involved in doing all this may be sufficient to account for the relative failure of the conditional. As Wason and Johnson-Laird (1969) state

> "...It is as if the 'either...or' expression itself creates uncertainty. It breaks up the 'direction' which seems to be strongly imposed by the conditional, 'if...then' sentence. With a conditional the individual is likely to be confident but wrong; with a disjunction he is more likely to be unconfident but right. The meaning of a conditional gives no hint of the negation or falsity which underlies its logic. The disjunctive expression makes this element explicit, but this seems to weaken the grounds upon which any inference can be made." (pg. 20)

Thus, there seem to be inherent difficulties with the conditional expression.

In conditional reasoning, the proportion of subjects mastering the items of the detachment principle is very much larger than that mastering the items of the contraposition, conversion and inversion principles. The difficulty of these three principles relative to the detachment principle is present at all three educational levels. Wason's (1968) interpretation for the difficulty of these three principles is of relevance. His explanation depends upon two assumptions. First,

> "...individuals are not constrained by the rules of propositional logic. They implicitly assume that a conditional sentence can have three outcomes or truth

values: p.q is true, p.$\bar{q}$ is false and $\bar{p}$ with either q or $\bar{q}$ is irrelevant." (pg. 274)

This assumption explains why the invalid inference conversion occurs: q is selected in order to see whether it is associated with p making the conditional true. It also explains why the invalid inference inversion happens: $\bar{p}$ is irrelevant to the truth or falsity of the sentence.

Wason's (1968) second assumption explains the infrequency of the contrapositive inference; why $\bar{p}$ is so seldom deduced from $\bar{q}$. This assumption states:

> "...individuals are biased, through a long learning process, to expect a relation or truth, correspondence or match to hold between sentences and states of affairs. In adult experience truth is encountered more frequently than falsity, and we seldom use a proposition or judgement that something is false in order to make a deduction."

In other words, having convinced themselves that p.q was true, subjects rarely used the transformation (p.q.) $\equiv$ ($\bar{p}$.$\bar{q}$) to test the truth value of $\bar{p}$.$\bar{q}$; apparently they regarded this association as being irrelevant. (pg. 274)

These explanatory assumptions of Wason seem to accord with the present finding. Thus, it seems most likely that our subjects do indeed reason as he has postulated.

To summarise, the results of teenagers' ability to master deductive arguments based on four principles of conditional and disjunctive reasoning, is very largely consistent with the findings of previous publications in this area. The findings specific to this study include:

(i) In conditional reasoning, subjects find no dif-

ference between items embedded in the concrete and abstract content.

(ii) In conditional reasoning, subjects find the valid principle contraposition to be just as difficult as the invalid principles of conversion and inversion; and

(iii) In disjunctive reasoning, subjects find no difference between the valid and the invalid principles.

A partial explanation to account for the first discrepancy has been presented. In addition, all three differences observed in the present study may be due to the limited range of scores in each principle subtest. This range between zero and three in each principle subtest may not have provided enough discrimination between them when finer distinctions are needed.

Having thus established the similarities and differences between the present study and previous publications on teenagers' ability to master deductive arguments; the next objective is to suggest some factors which may influence the subjects' deductive ability to reason.

In reasoning experiments, subjects are normally required to infer conclusions from given premises or to evaluate the truth of logical statements in relation to given evidence. A common feature of these studies is that an arbitrary criterion of the correctness of subjects' responses is provided by the rules of propositional logic. Experimenters have tended to be over-influenced by the logical structures of the problems when interpreting the observed behaviour or their subjects and have tended to overlook for explanations quite unconnected with logic. An example would be the "atmospheric effect" of syllogistic inference (Woodworth and Sells, 1935; Sells, 1936): subjects are

assumed to ignore the logical structure of the problems and evaluate the conclusions of the argument according to whether they match the atmosphere of the premises. For example, a premise containing a negative creates a bias towards choosing a conclusion which contains a negative.

In reasoning and language comprehension, there are both linguistic and non-linguistic factors that influence the manner in which individuals may glean information from sentences. Such a sentence contains linguistic information about the content as well as the relation between the antecedent (p) and the consequent (q) propositions. Specifically, the content of the proposition can be abstract or symbolic, or semantically concrete and meaningful. In addition, the semantic relation between concrete propositions can express, for example, attribute description or causality. And finally, there is the connective logically joining the propositions, which may be the conditional "if...then"; some semantic equivalent such as "since" or "because"; or even a logically different connective such as the disjunctive "either...or".

These variables are linguistic in that they explicitly contribute to the structure of the sentence and, taken independently, all have some denotative meanings as assigned by semantics. The complete interpreted meaning of a sentence is usually not entirely given by the denotative meaning in the linguistic structure of the sentence. Instead, the complete meaning of an expression usually encompasses connotation as well. Connotative meaning is interpreted not from the linguistic structure of the sentence but from non-linguistic, pragmatic factors pertaining to the use of the sentence which include empirical knowledge of the world as well as contextual presuppositions.

In addition, the "matching bias" effect suggested by Evans (1972a) is another variable which may affect the subjects' ability to reason. In the original experiment subjects are asked to construct verifying and falsifying cases of conditional rules, in which the presence and absence of negative components were systematically varied.[1] A totally unexpected factor dominated the results: subjects tended to choose values which matched rather than altered values named in the rules, irrespective of the presence of negatives. For example, when asked to falsify a rule such as "If there is not a red triangle on the left then there is a blue circle on the right", most subjects placed a red triangle to the left of a blue circle. Logically this constitutes a combination of a false antecedent and a true consequent. The logically correct combination, true antecedent and false consequent, was least often given on this rule, which is the only one where alteration of both named values would be necessitated, e.g. by placing a green square to the left of a blue triangle. Thus, Evans states

> "...It would seem that the subjects' understanding of an 'if...then' sentence entails some appreciation of when the rule may be true or false, but for cases where such influence is weak the operational effects of matching takes over. The relative effects of matching suggest that while the false antecedent cases are psychologically 'irrelevant' (Wason, 1966) subjects are more competent at the task of verification than falsification."

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[1] Four rules were used of the general form: if p then q, if p then not q, if not p then q and if not p then not q.

These "non-logical" factors must be considered in evaluating reasoning. These factors interact with the logical form in that they influence the interpretation of the task and the material employed. Wundt (1880) long ago pointed out the necessity of considering the global structure of knowledge and the variety of processing strategies an individual possesses and uses to interpret information. Thus, the requirements of the task as well as the information individuals are asked to make inferences about are not dealt with in isolation but rather become the focal point of the total picture within an interactive, global system.

The final objective of the discussion is to present some implications for the kind of study we have carried out. Besides the general theoretical interest of such a study to developmental specialists, studies in this area provide information about teenagers' ability to master deductive arguments. This is done by providing information about the way teenagers use conditional and disjunctive reasoning. The results of the present study show that teenagers find disjunctive reasoning easier to master than conditional reasoning, and that they do know some of the fundamental principles of these two types of reasoning. The results of the present study also indicate possible sources of difficulty (e.g. the presence of negatives) implicit in the given propositions. Studies in the area of propositional logic further provide information concerning the current level of cognitive operations in teenagers as they result from current and past life experiences. This kind of information is important because of the shortage of empirical experimental research during teenage years, especially in teenagers'

development of disjunctive reasoning. Thus, the area of disjunctive logic provides obvious lines of research which need to be developed.

One of the widely accepted objectives of education in general is to help students think critically. One aspect of critical thinking is the ability to test the logical validity of an argument. This is an important ability in everyday life when arguments such as "Communists favour U.S. withdrawal from Vietnam. Bill favours U.S. withdrawal from Vietnam. Therefore, Bill is a Communist" are widely accepted as valid. Thus, it is necessary to implement this concept of critical thinking in students.

Another implication of such work can be found in the concept of "economy of thought"; whereby arguments can be expressed in more efficient logical forms.

Finally, a potential implication of such work is in the area of computer programming. With the increasing use of computers in schools, it is essential for the students to acquire the necessary programming skills. As computer programmers normally make use of the basic principles of logic in constructing sentences, it is necessary for the students to be acquainted with these logical principles. Once they are familiar with the basic principles of propositional logic, it may well be much easier for them to acquire programming skills.

Conclusions

Both parametric and non-parametric analyses indicate that mastery of the four basic principles of deductive logic improves with age. Further, the results indicate no difference

between the two sexes relative to their performance on the reasoning test. The results indicate that subjects find no difference between items embedded in the concrete and the abstract content. The results also show that there are differences between subjects' mastery of the detachment principle and the other three principles of conditional reasoning. In contrast, there is no difference between subjects' mastery of the four principles of disjunctive reasoning. Finally, the results show that subjects find items within disjunctive reasoning easier to master than those within conditional reasoning. These results on teenagers' ability to master deductive arguments are consistent with the findings of previous publications in this area. The findings specific to this study include:

(i) In conditional reasoning, subjects find no difference between items embedded in the concrete and the abstract content;

(ii) In conditional reasoning, subjects find the valid principle contraposition to be just as difficult as the invalid principles of conversion and inversion; and

(iii) In disjunctive reasoning, subjects find no difference between the valid and the invalid principles.

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APPENDIX I

THE REASONING TEST

USE OF LOGICAL PRINCIPLES

Part I

YOU CAN CHOOSE YES, NO, MAYBE

where

"YES" means "THE ANSWER MUST BE TRUE"

"NO" means "THE ANSWER CANNOT BE TRUE", and

"MAYBE" means "THE ANSWER MAY BE TRUE OR MAY NOT BE TRUE. YOU WERE NOT TOLD ENOUGH TO BE CERTAIN WHETHER THE ANSWER IS 'YES' OR 'NO'."

EXAMPLE ONE:

SUPPOSE YOU KNOW

IF THE COAT IS BROWN, THEN IT BELONGS TO MR SMITH.

THE COAT IS BROWN.

THEN WOULD THIS BE TRUE:

THE COAT BELONGS TO MR SMITH?

- [x] YES
- [ ] NO
- [ ] MAYBE

Tick the correct answer.

The answer in this example is YES for if the coat is brown, then it belongs to Mr Smith.

EXAMPLE TWO:

SUPPOSE YOU KNOW

IF THE COAT IS BROWN, THEN IT BELONGS TO MR SMITH.

THE COAT BELONGS TO MR SMITH.

THEN WOULD THIS BE TRUE:

THE COAT IS BROWN?

- [ ] YES
- [ ] NO
- [x] MAYBE

The answer in this example is MAYBE for the coat belonging to Mr Smith might not necessarily be brown.

EXAMPLE THREE:

SUPPOSE YOU KNOW

EITHER DON IS TALL OR DON IS THIN (OR DON IS BOTH TALL AND THIN).

DON IS NOT TALL. ☑ YES

THEN WOULD THIS BE TRUE: ☐ NO

DON IS THIN? ☐ MAYBE

The answer in this example is YES for given that Don is not tall, then he must be thin.

1. Suppose you know
   If the cat is black, then its name is Kitty.
   The cat is black.
   Then would this be true:
   The cat's name is Kitty?

☐ YES
☐ NO
☐ MAYBE

2. Suppose you know
   If the picture belongs to Mary, then it is a picture of a girl.
   It is a picture of a girl.
   Then would this be true:
   The picture belongs to Mary?

☐ YES
☐ NO
☐ MAYBE

3. Suppose you know
   If the dog's name is Lassie, then she is white.
   The dog is not white.
   Then would this be true:
   The dog's name is Lassie?

☐ YES
☐ NO
☐ MAYBE

4. Suppose you know
   If the dog is brown, then its name is Rover.
   The dog is not brown.
   Then would this be true:
   The dog's name is not Rover?

☐ YES
☐ NO
☐ MAYBE

5. Suppose you know
   If the scarf is yellow, then it belongs to Sue.
   The scarf belongs to Sue.
   Then would this be true:
   The scarf is yellow?

☐ YES
☐ NO
☐ MAYBE

6. Suppose you know
   If Peter goes to the fair, then he will meet his friend John.
   Today, Peter is going to the fair.
   Then would this be true:
   Today, Peter will meet his friend John?

☐ YES
☐ NO
☐ MAYBE

7. Suppose you know
   If the car in the garage is Mr Smith's, then it is black.
   The car in the garage is not Mr Smith's.
   Then would this be true:
   The car is not black?

☐ YES
☐ NO
☐ MAYBE

8. Suppose you know
   If the car is black, then it is a police car.
   It is not a police car.
   Then would this be true:
   The car is black?

☐ YES
☐ NO
☐ MAYBE

9. Suppose you know
   If the cat's name is Tammy, then she is white.
   The cat's name is not Tammy.
   Then would this be true:
   The cat is not white?

☐ YES
☐ NO
☐ MAYBE

10. Suppose you know
    If the ball in the garden is white, then it belongs to John.
    The ball in the garden is white.
    Then would this be true:
    The ball belongs to John?

☐ YES
☐ NO
☐ MAYBE

11. Suppose you know
    If Peter is tall, then Don is short.
    Don is not short.
    Then would this be true:
    Peter is tall?

☐ YES
☐ NO
☐ MAYBE

12. Suppose you know
    If the box is brown, then it contains a dozen plates.
    The box contains a dozen plates.
    Then would this be true:
    The box is brown?

☐ YES
☐ NO
☐ MAYBE

13. Suppose you know
    Either the car is new or the car is white (or the car is both new and white).
    The car is not white.
    Then would this be true:
    The car is new?

☐ YES
☐ NO
☐ MAYBE

14. Suppose you know
    Either Peter is rich or Peter is stupid (or Peter is both rich and stupid).
    Peter is rich.
    Then would this be true:
    Peter is stupid?

☐ YES
☐ NO
☐ MAYBE

15. Suppose you know
    Either the gate is open or the gate is green (or the gate is both open and green).
    The gate is not open.
    Then would this be true:
    The gate is green?

☐ YES
☐ NO
☐ MAYBE

16. Suppose you know
    Either the dog is black or the dog is dirty (or the dog is both black and dirty).
    The dog is not dirty.
    Then would this be true:
    The dog is black?

☐ YES
☐ NO
☐ MAYBE

17. Suppose you know
Either the car is small or the car is blue (or the car is both small and blue).
The car is small.
Then would this be true:
The car is blue?

☐ YES
☐ NO
☐ MAYBE

18. Suppose you know
Either John is intelligent or John is rich (or John is both intelligent and rich).
John is not intelligent.
Then would this be true:
John is rich?

☐ YES
☐ NO
☐ MAYBE

19. Suppose you know
Either the door is closed or the door is white (or the door is both closed and white).
The door is white.
Then would this be true:
The door is closed?

☐ YES
☐ NO
☐ MAYBE

20. Suppose you know
Either the shed is old or the shed is grey (or the shed is both old and grey).
The shed is old.
Then would this be true:
The shed is grey?

☐ YES
☐ NO
☐ MAYBE

21. Suppose you know
Either Peter is lazy or Peter is sick (or Peter is both lazy and sick).
Peter is not sick.
Then would this be true:
Peter is lazy?

☐ YES
☐ NO
☐ MAYBE

22. Suppose you know
Either the cat is hungry or the cat is sick (or the cat is both hungry and sick).
The cat is sick.
Then would this be true:
The cat is hungry?

☐ YES
☐ NO
☐ MAYBE

23. Suppose you know
Either the house is old or the house is white (or the house is both old and white).
The house is not old.
Then would this be true:
The house is white?

☐ YES
☐ NO
☐ MAYBE

24. Suppose you know
Either John is fat or John is short (or John is both fat and short).
John is short.
Then would this be true:
John is fat?

☐ YES
☐ NO
☐ MAYBE

Part 2

YOU CAN CHOOSE YES, NO, MAYBE

where
"YES" means "THE ANSWER MUST BE TRUE",
"NO" means "THE ANSWER CANNOT BE TRUE", and
"MAYBE" means "THE ANSWER MAY BE TRUE OR MAY NOT BE TRUE. YOU WERE NOT TOLD ENOUGH TO BE CERTAIN WHETHER THE ANSWER IS 'YES' OR 'NO'."

EXAMPLE ONE

SUPPOSE YOU KNOW
IF THE CIRCLE IS RED, THEN THE SQUARE IS BLUE.

THE CIRCLE IS RED.

THEN WOULD THIS BE TRUE:
THE SQUARE IS BLUE?

- [x] YES
- [ ] NO
- [ ] MAYBE

The answer in this example is YES for if the circle is red, than the square is blue.

EXAMPLE TWO

SUPPOSE YOU KNOW
EITHER THE CIRCLE IS GREEN OR THE SQUARE IS GREEN (OR BOTH THE CIRCLE AND THE SQUARE ARE GREEN).

THE CIRCLE IS GREEN.

THEN WOULD THIS BE TRUE:
THE SQUARE IS GREEN?

- [ ] YES
- [ ] NO
- [x] MAYBE

The answer in this example is MAYBE for given the circle is green, the square may or may not be green.

1. Suppose you know
   If the circle is red, then the triangle is blue.
   The circle is red.
   Then would this be true:
   The triangle is blue?

☐ YES
☐ NO
☐ MAYBE

2. Suppose you know
   If the circle is blue, then the square is red.
   The square is red.
   Then would this be true:
   The circle is blue?

☐ YES
☐ NO
☐ MAYBE

3. Suppose you know
   If the square is blue, then the triangle is green.
   The triangle is not green.
   Then would this be true:
   The square is blue ?

☐ YES
☐ NO
☐ MAYBE

4. Suppose you know
   If the square is green, then the triangle is red.
   The square is not green.
   Then would this be true:
   The triangle is not red?

☐ YES
☐ NO
☐ MAYBE

5. Suppose you know
   If the circle is red, then the triangle is green.
   The triangle is green.
   Then would this be true:
   The circle is red?

☐ YES
☐ NO
☐ MAYBE

6. Suppose you know
   If the square is green, then the circle is blue.
   The square is green.
   Then would this be true:
   The circle is blue?

☐ YES
☐ NO
☐ MAYBE

7. Suppose you know
   If the circle is red, then the square is blue.
   The circle is not red.
   Then would this be true:
   The square is not blue?

☐ YES
☐ NO
☐ MAYBE

8. Suppose you know
   If the circle is red, then the square is green.
   The square is not green.
   Then would this be true:
   The circle is red?

☐ YES
☐ NO
☐ MAYBE

9. Suppose you know
   If the triangle is green, then the square is red.
   The triangle is not green.
   Then would this be true:
   The square is not red?

☐ YES
☐ NO
☐ MAYBE

10. Suppose you know
    If the triangle is blue, then the square is red.
    The triangle is blue.
    Then would this be true:
    The square is red?

☐ YES
☐ NO
☐ MAYBE

11. Suppose you know
    If the square is blue, then the triangle is red.
    The triangle is not red.
    Then would this be true:
    The square is blue?

☐ YES
☐ NO
☐ MAYBE

12. Suppose you know
    If the square is green, then the triangle is blue.
    The triangle is blue.
    Then would this be true:
    The square is green?

☐ YES
☐ NO
☐ MAYBE

13. Suppose you know
    Either the square is red or the circle is red (or both the square and the circle are red)
    The circle is not red.
    Then would this be true:
    The square is red?

☐ YES
☐ NO
☐ MAYBE

14. Suppose you know
    Either the circle is green or the triangle is green (or both the circle and the triangle are green).
    The circle is green.
    Then would this be true:
    The triangle is green?

☐ YES
☐ NO
☐ MAYBE

15. Suppose you know
    Either the square is red or the triangle is red (or both the square and the triangle are red).
    The square is not red.
    Then would this be true:
    The triangle is red?

☐ YES
☐ NO
☐ MAYBE

16. Suppose you know
    Either the square is green or the triangle is green (or both the square and the triangle are green).
    The triangle is not green.
    Then would this be true:
    The square is green?

☐ YES
☐ NO
☐ MAYBE

17. Suppose you know
Either the square is blue or the circle is blue (or both the square and the circle are blue).
The square is blue.
Then would this be true:
The circle is blue?

☐ YES
☐ NO
☐ MAYBE

18. Suppose you know
Either the circle is green or the square is green (or both the circle and the square are green).
The circle is not green.
Then would this be true:
The square is green?

☐ YES
☐ NO
☐ MAYBE

19. Suppose you know
Either the triangle is red or the square is red (or both the triangle and the square are red).
The square is red.
Then would this be true:
The triangle is red?

☐ YES
☐ NO
☐ MAYBE

20. Suppose you know
Either the triangle is red or the circle is red (or both the triangle and the circle are red).
The triangle is red.
Then would this be true:
The circle is red?

☐ YES
☐ NO
☐ MAYBE

21. Suppose you know
Either the square is blue or the circle is blue (or both the square and the circle are blue).
The circle is not blue.
Then would this be true:
The square is blue?

☐ YES
☐ NO
☐ MAYBE

22. Suppose you know
Either the triangle is green or the circle is green (or both the triangle and the circle are green).
The circle is green.
Then would this be true:
The triangle is green?

☐ YES
☐ NO
☐ MAYBE

23. Suppose you know
Either the circle is blue or the square is blue (or both the circle and the square are blue).
The circle is not blue.
Then would this be true:
The square is blue?

☐ YES
☐ NO
☐ MAYBE

24. Suppose you know
Either the square is red or the circle is red (or both the square and the circle are red).
The circle is red.
Then would this be true:
The square is red?

☐ YES
☐ NO
☐ MAYBE

APPENDIX II

GENERAL INSTRUCTIONS USED IN THE REASONING TEST

The following instructions were read out to the students prior to testing.

"Turn to the front page of the booklet; these are examples to help you in answering the questions later. I will go through these examples, and if you are not clear about any of them, please ask.

In the box at the top of the first page, is written:
'You can choose Yes, No, Maybe, where
'Yes' means 'The answer must be true',
'No' means 'The answer cannot be true', and
'Maybe' means 'The answer may be true or may not be true. You were not told enough to be certain whether the answer is "Yes" or "No".'

EXAMPLE ONE

Suppose you know

If the coat is brown, then it belongs to Mr Smith.

The coat is brown

Then would this be true:

The coat belongs to Mr Smith?

The answer in this example is Yes for if the coat is brown, then it belongs to Mr Smith.

EXAMPLE TWO

Suppose you know

If the coat is brown, then it belongs to Mr Smith.

The coat belongs to Mr Smith.

Then would this be true:

The coat is brown?

The answer in this example is Maybe for the coat belonging to Mr Smith might not necessarily be brown.

EXAMPLE THREE

Suppose you know

Either Don is tall or Don is thin (or Don is both tall and thin)

Don is not tall.

Then would this be true:

Don is thin?

The answer in this example is Yes for given that Don is not tall, then he must be thin.

In answering these questions, you have to consider all the possibilities. Remember,

'Yes' means 'The answer must be true'

'No' means 'The answer cannot be true', and

'Maybe' means 'The answer may be true or may not be true. You were not told enough to be certain whether the answer is "Yes" or "No".'

There are two parts to the tests, Part 1 and Part 2. After you have finished with Part 1, read through the examples of Part 2 before proceeding with the following questions. Are there any questions?

Before you start, please write down your dates of birth and your sexes."